CA3ONHWQ60
80P44

NING FOR LOW DENSITY

A SOLAR APPROACH

I
UARY

II
FEBRUARY

III
MARCH

IV
APRIL

V
MAY

VI
JUNE

VII
JULY

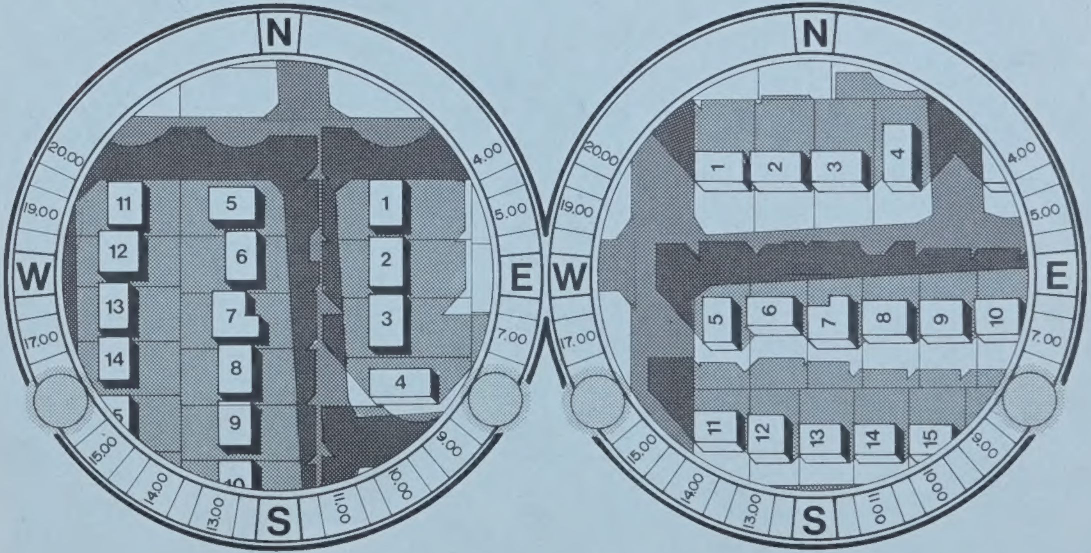
VIII
AUGUST

IX
SEPTEMBER

X
OCTOBER

XI
NOVEMBER

XII
DECEMBER


N
S
E
W
20.00
19.00
17.00
15.00
14.00
13.00
11.00
10.00
9.00
7.00
5.00
4.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

PREPARED FOR THE
CITY OF HAMILTON
BY THE PLANNING AND DEVELOPMENT DEPARTMENT
REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

JULY '80

HAMILTON PUBLIC LIBRARY
MAR [illegible] 1981
GOVERNMENT DOCUMENTS

PLANNING FOR LOW DENSITY — A SOLAR APPROACH

PLANNING AND DEVELOPMENT DEPARTMENT REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH CITY HALL HAMILTON ONTARIO CANADA L8N 3T4

Digitized by the Internet Archive
in 2024 with funding from
Hamilton Public Library

https://archive.org/details/planningforlowde00unse

ACKNOWLEDGEMENTS

SINCE THE SUBJECT OF THIS REPORT IS ENORMOUSLY WIDE AND COMPLEX, INEVITABLY THE TREATMENT OF SOME PROBLEMS MIGHT BE UNEVEN AND PERHAPS SUPERFICIAL. IN ADDITION, WE DO NOT WISH TO PRETEND THAT THE WHOLE IS ORIGINAL SINCE IN MANY PARTICULAR AREAS WE HAD TO RELY ON A NUMBER OF OUTSIDE SOURCES WHICH EXAMINED AND DISCUSSED INDIVIDUAL PROBLEMS MORE EXPERTLY THAN WE COULD HAVE DONE. SOME ORIGINALITY MIGHT BE FOUND IN THE WAY THE VAST AMOUNT OF DATA WAS COMPILED, DIGESTED AND TRANSPORTED INTO RELATIVELY SIMPLE, USEFUL TOOLS FOR EVERYDAY USE.

OUR IDENBTEDNESS TO MANY PUBLISHED SOURCES IS OBVIOUS FROM THE SIZE OF THE BIBLIOGRAPHY.

MANY AGENCIES AND INSTITUTIONS ASSISTED US BY KINDLY PROVIDING US WITH ENVIRONMENTAL DATA AND OTHER INFORMATION.

WE ARE PARTICULARLY THANKFUL TO THE FOLLOWING:

ENVIRONMENT CANADA, ATMOSPHERIC ENVIRONMENT.

HAMILTON AIRPORT, MOUNT HOPE, ONTARIO.

CANADIAN CLIMATE CENTRE, DOWNSVIEW, ONTARIO.

ROYAL BOTANICAL GARDENS, WEATHER OFFICE.

THIS IS THE THIRD REPORT ON ENERGY CONSERVATION PRODUCED BY THE PLANNING DEPARTMENT OF THE HAMILTON-WENTWORTH REGION. THE TWO PREVIOUS REPORTS WERE:

- ENERGY CONSIDERATION IN URBAN AND REGIONAL PLANNING (JANUARY, 1978); AND,
- OPPORTUNITIES FOR ENERGY SAVINGS IN HIGH-DENSITY URBAN DEVELOPMENTS (AUGUST, 1979).

NOTE

- TO ASSIST PLANNERS AND TO IMPROVE SUBDIVISION DESIGN;
- TO ASSIST DESIGN PROFESSIONALS, DEVELOPERS AND HOME BUILDERS IN PREPARATION OF DEVELOPMENT PROPOSALS; AND,
- AROUSE GENERAL AWARENESS OF THE LINK BETWEEN LIFESTYLE AND ENERGY CONSUMPTION.

PURPOSE OF THE REPORT

PAGE

PREFACE 1

INTRODUCTION 2

SOLAR - THE BASICS 6

- SOLAR ENERGY 7
- THE SUN'S POSITION IN THE SKY 8
- SOLAR RADIATION 9
- REFLECTION OF SOLAR RADIATION 10
- SUN WINDOW 11

SOLAR - ACTIVE 12

- ACTIVE SOLAR ENERGY SYSTEM 13
- SOLAR COLLECTOR ANGLE 14

TABLE OF CONTENTS

PAGE

SOLAR - PASSIVE 1 15
  Elements of a Passive Solar System 17
  The Mechanics of a Passive Solar System 18
  Passive Solar Design Principles 19
  House Orientation and Thermal Comfort 21
  Solar Landscaping 22
  Overhang 24
  Heat Loss 25
SOLAR - PASSIVE 2 26
  Direct Passive Gain 27
  Indirect Passive Gain 28
  Sunspace System 29
  Mass Roof 30
  Double Shell 31

PAGE

EARTH SHELTERING 32

- Variation of Soil Temperature 33
- Earth-Sheltered Houses 34

SOLAR PASSIVE - PLANNING CONSIDERATIONS 36

- Subdivision Orientation and Shadow Casting 37
- Typical Example of Existing Subdivision - 40′ x 110′ Lot 38
- Typical Example of Existing Subdivision - 40′ x 100′ Lot 39
- Typical Example of Existing Subdivision - 35′ x 90′ Lot 40
- Existing Developable Space (Envelope) 41
- Derivation of the Proposed Developable Space (Envelope) 42
- Proposed Developable Space (Envelope) - 110′ Lot 43
- Proposed Developable Space (Envelope) - 100′ Lot 44
- Proposed Developable Space (Envelope) - 90′ Lot 45
- Proposed Developable Space (Envelope) - 80′ Lot 46
- Proposed Developable Space (Envelope) - 70′ Lot 47

PAGE

OTHER CONSIDERATIONS 48

Design 49

Heat Pump 51

District Heating 52

SHADOW TEMPLATES 54

Shadow Pattern - Task 1 55

Shadow Pattern - Tasks 2 and 3 56

Shadow Pattern - Task 4 57

Shadow Pattern - Task 5 58

ECOCHART OF HAMILTON 74

CONCLUSIONS 81

BIBLIOGRAPHY 87

APPENDICES ....

ONCE UPON A TIME, A HANDFUL OF INDIVIDUALS HAD THE "CHUTZPAH" TO SAY THAT ENERGY IS SCARCE, TO BE SAVED AND NOT WASTED, THAT WE SHOULD BUILD OUR HOMES AND COMMUNITIES IN A DIFFERENT MANNER, AND THAT OUR LIFESTYLE SHOULD BE CHANGED.

THEY WERE IGNORED.

LATER, MORE RESPECTABLE AND LARGER GROUPS SAID THE SAME. THE REACTION WAS A MIXTURE OF AMUSEMENT AND DISBELIEF...

THOSE DAYS ARE OVER. THE LAUGHTER HAS DIED.

THE MATTER IS NOW A DEADLY SERIOUS ONE.

PREFACE

In case a true energy shortage occurs, the subdivision dweller is potentially the most vulnerable. It requires enormous amounts of various types of energies to support the present suburban land use arrangement. The cost of these energies is slowly reaching a limit in terms of the paying capacity of individual homeowners, as well as municipalities. Thus, energy consideration in planning low-density developments appears to be the most urgent, as well as the most controversial, and perplexing problem. It has been suggested that even linking "energy efficiency" and "low-density development" constitutes a paradox since urban sprawl is the prime cause of the present energy and environmental overload.

Furthermore, a difficulty lies in the fact that a wastage of energy is, of course, very wrong, but at the same time, immensely delightful. Thus, it is not hard to understand how a two-garage subdivision home built far away from working, shopping, educational and recreational facilities became the great dream for the average North American. In the last few decades, this love affair with a single-family house and a personal car fleet reached mass proportions.

AND THE IDEA OF ENJOYING "THE GOOD LIFE" OUTSIDE OF A SUBDIVISION WAS BELIEVED TO BE IMPOSSIBLE. HOMEOWNERSHIP BECAME A PART OF OUR BASIC HUMAN RIGHTS AND THIS BELIEF WAS REINFORCED BY A VARIETY OF GOVERNMENTAL PROGRAMS AND SUBSIDIES. ALTHOUGH THE MARKET MECHANISM WAS GROSSLY DISTORTED, THE BLUEPRINT FOR HAPPINESS WAS ESTABLISHED.

CONSEQUENTLY, THE OVERALL PROCESS OF DEVELOPING A SUBDIVISION - FROM ITS INCEPTION TO ITS SALES CLOSINGS - HAS BEEN STREAMLINED AND ALL THE INVOLVED PARTIES HAVE LEARNED TO PLAY THEIR ROLES. THE SYSTEM APPEARED TO BE VERY SUCCESSFUL AND ATTRACTED WORLD-WIDE ATTENTION AND ENVY.

THUS, IT WAS UNTIL VERY RECENTLY. SUDDENLY, OVERWHELMING EVIDENCE WAS PRESENTED TO SHOW THAT A FUNDAMENTAL ERROR WAS OVERLOOKED: OUR DISREGARD FOR THE COST OF ENERGY AND FOR THE AMOUNT OF ENERGY CONSUMED. A SLAP IN THE FACE...A PUNISHMENT FOR OUR BLINDNESS. BUT, WHAT CAN WE DO NOW?

INEVITABLY, BUT UNDERSTANDABLY, ANY ATTEMPT TO ALTER THE PRESENT WAY OF DOING THINGS MUST MEET

WITH FURIOUS RESISTANCE ON THE PART OF EVERYONE INVOLVED: THE LUMBER INDUSTRY, MANUFACTURERS, LAND DEVELOPERS, BUILDERS, ARCHITECTS, PLANNERS, FINANCIAL INSTITUTIONS, MUNICIPAL [illegible], PROVINCIAL AND FEDERAL AUTHORITIES, REALTORS, AND, OF COURSE, THE [illegible]. [illegible] THE CONSTRUCTION INDUSTRY IS OPERATING ON A MUCH LOWER PROFIT MARGIN [illegible] ARE ULTRA-SENSITIVE TO THE SENTIMENTS OF THE MARKET. THE VICIOUS CIRCLE APPEARS TO BE CLOSED.

HOW, UNDER THESE CIRCUMSTANCES, CAN WE INTRODUCE A BETTER WAY OF DOING THINGS?

EVEN A CURSORY ANALYSIS OF THE PRESENT SITUATION WOULD CONVINCE US THAT ANY EFFECTIVE ACTION WOULD REQUIRE THE CO-OPERATION OF ALL THE PARTIES INVOLVED. FIRST, THERE IS A NEED FOR CO-OPERATION IN TERMS OF A COLLECTIVE AGREEMENT AND SUPPORT FOR THE NECESSARY CHANGES, AND SECONDLY, THERE IS A NEED FOR CO-OPERATION BETWEEN INDIVIDUAL PARTIES. AS NEVER BEFORE, THE DEVELOPER, THE MUNICIPAL PLANNER, THE ARCHITECT AND THE REALTOR MUST WORK CLOSE TOGETHER. WITHOUT THIS CONCERTED EFFORT, ANY ATTEMPT TO BUILD ENERGY-EFFICIENT COMMUNITIES WOULD BE A FUTILE EXERCISE.

GREAT EMPHASIS HAS TO BE PLACED ON EDUCATION AND INFORMATION DISSEMINATION. THIS HAS BEEN DONE FOR SOME TIME NOW, AND WE ARE CONTINUING TO DO SO. BUT TO CONVINCE AND SECURE CO-OPERATION ON THE REQUIRED SCALE DEMANDS MORE TIME. IT FOLLOWS THEN THAT WE ARE NOT GOING TO EXPERIENCE ANY DRAMATIC CHANGES OVERNIGHT. THE PROCESS OF TRANSFORMATION WILL BE GRADUAL.

SINCE WE WISH TO PROCEED WITH CHANGES AS SLOWLY AS CIRCUMSTANCES ALLOW US TO, WE WOULD LIKE TO BEGIN WITH SIMPLE, INEXPENSIVE IMPROVEMENTS. TO BE VERY EFFICIENT DOES NOT ALWAYS REQUIRE "BUCK ROGERS" STYLE TECHNOLOGIES. THERE ARE MANY MINOR ADJUSTMENTS AND "SOFT PATHS" TO FOLLOW WHICH, IN SUMMARY, COULD ACCOMPLISH UP TO A 50% CUT ON ENERGY CONSUMPTION WITHOUT ANY DRACONIAN MEASURES APPLIED.

THE FIRST STEP IN THIS DIRECTION IS TO LEARN - OR RE-LEARN - THE USE OF COMMON SENSE: HOW TO TAKE ADVANTAGE OF THE NATURAL ENVIRONMENT, HOW TO BUILD HOUSES WHICH WARM THE PEOPLE INSIDE AND NOT THE SKY.

THIS REPORT IS DEVOTED TO THIS FIRST STEP.

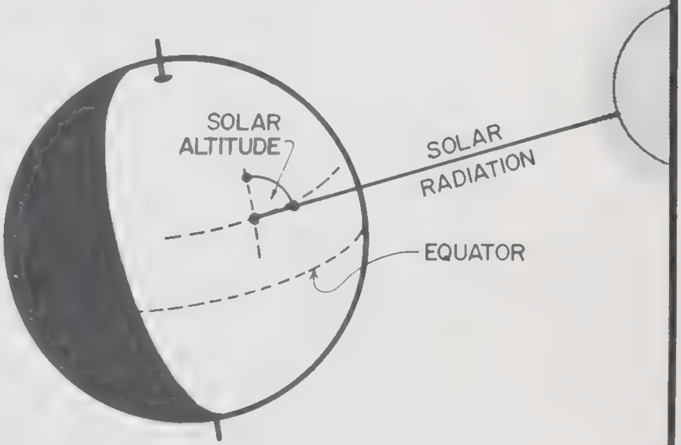
THE ABSOLUTE MINIMUM WE HAVE TO KNOW ABOUT THE SUN, [illegible]

THAT PART OF THE SKY WHICH SHOULD BE CONSIDERED OUR GOD-GIVEN [illegible] CALLED A "SKY WINDOW".

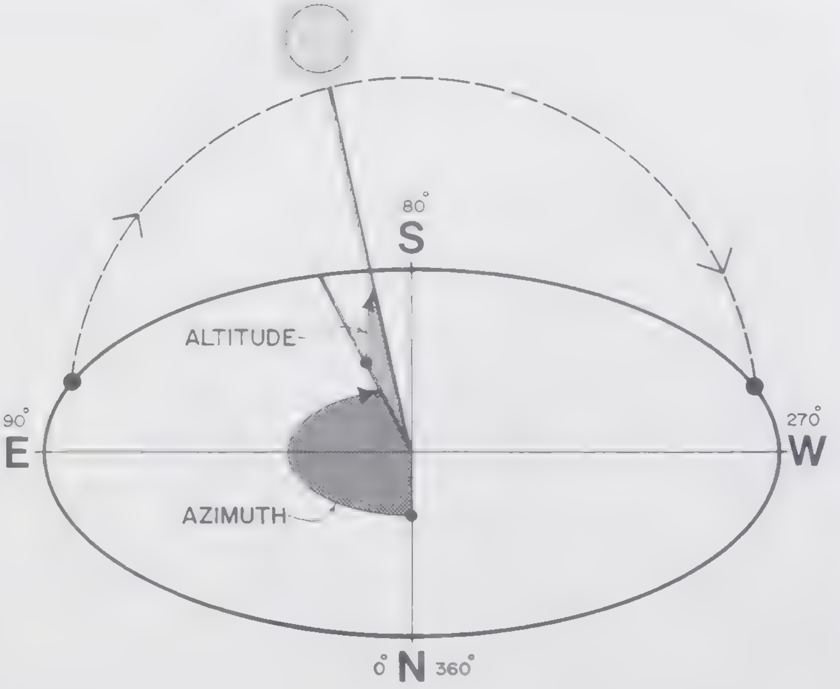
THE MORE SUNLIGHT A SIGHT RECEIVES, THE GREATER IS IT'S POTENTIAL FOR USING SOLAR ENERGY THE AMOUNT OF SUNLIGHT A GIVEN SPOT ON EARTH RECEIVES DEPENDS ON HOW NEAR TO PERPENDICULAR THE SUN'S RAYS ARE TO THE SITE THE CLOSER THE SUN IS TO BEING DIRECTLY OVERHEAD, THE GREATER IS ITS INTENSITY; THE MORE TILTED THE SUN IS FROM THE PERPENDICULAR, THE LESS INTENSE ARE ITS RAYS

THE AMOUNT OF ENERGY RECEIVED FROM THE SUN AT A GIVEN LOCATION DEPENDS ON THREE FACTORS THE TIME OF DAY, THE LATITUDE, AND THE TIME OF YEAR

THE SUN'S LIGHT IS MOST INTENSE AT SOLAR NOON, WHEN IT REACHES ITS HIGH POINT IN THE SKY FOR THE DAY, AND IT IS WEAKEST AT SUNRISE AND SUNSET THE SECOND FACTOR, LATITUDE, OR THE DISTANCE NORTH OR SOUTH OF THE EARTH'S EQUATOR, ALSO AFFECTS THE SUN'S POSITION IN THE SKY. BECAUSE OF THE EARTH'S CURVATURE, THE FURTHER NORTH ONE GOES IN THE NORTHERN HEMISPHERE, THE LOWER THE SUN AND THE LESS ITS INTENSITY FINALLY THE CHANGE OF SEASONS ALSO AFFECTS THE INTENSITY OF SUNLIGHT, PARTICULARLY IN LATITUDES DISTANT FROM THE EQUATOR IF THE EARTH'S AXIS WERE PERPENDICULAR TO THE PLANE OF THE EARTH'S ORBIT AROUND THE SUN, THERE WOULD BE NO CHANGE OF SEASON. SINCE THE EARTH'S AXIS IS TILTED AT ABOUT 23.5 DEGREES FROM THE PERPENDICULAR, THE NORTHERN HEMISPHERE IS TILTED SLIGHTLY TOWARDS THE SUN IN SUMMER AND SLIGHTLY AWAY FROM IT IN WINTER.

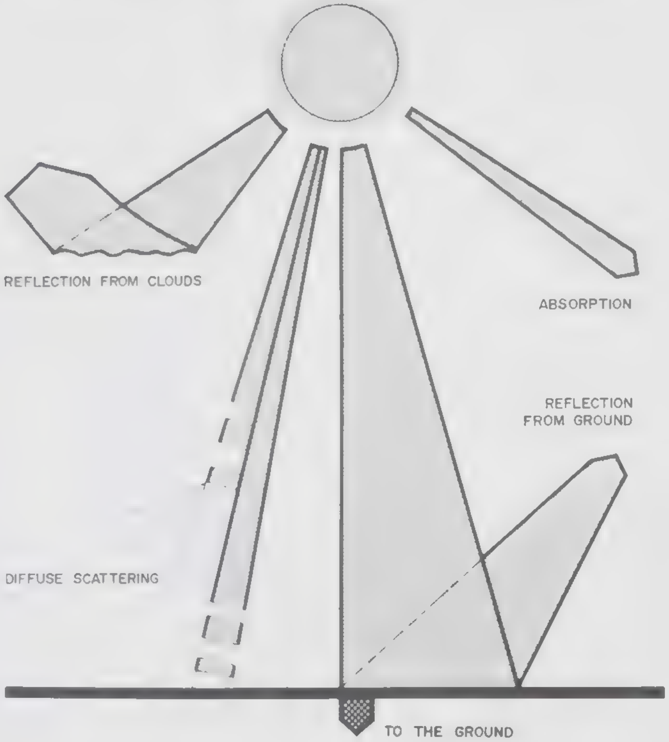


SOLAR ENERGY


80°
S
ALTITUDE
90°
E
270°
W
AZIMUTH
0°
N
360°

THE SUN'S POSITION IN THE SKY

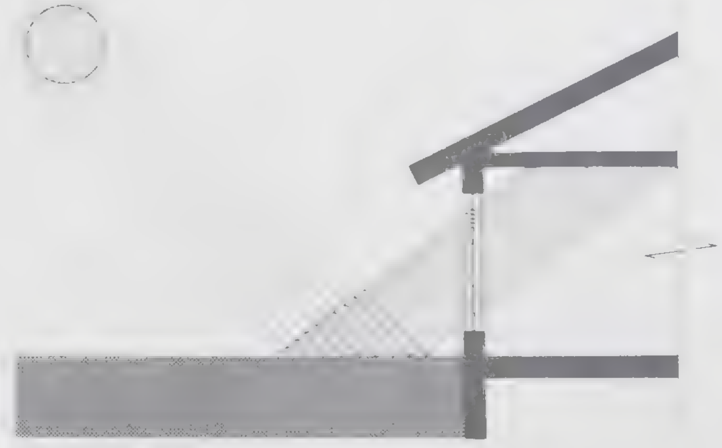
THE SOLAR RADIATION REACHING GROUND LEVEL IS CONSIDERABLY LESS BECAUSE OF A SERIES OF LOSSES WHICH OCCUR WHEN THE RADIATION PASSES THROUGH THE EARTH'S ATMOSPHERE. PART OF THE INCOMING SOLAR RADIATION IS REFLECTED BY THE SURFACE OF CLOUDS, AND ATMOSPHERIC INGREDIENTS. A CERTAIN AMOUNT IS SCATTERED BY MOLECULES IN THE ATMOSPHERE, BUT SOME OF THIS IS REGAINED AS DIFFUSE RADIATION PART OF THE RADIATION RECEIVED AT GROUND LEVEL IS REFLECTED BY THE EARTH'S SURFACE, BUT MOST OF THE ENERGY IS ABSORBED IT CHANGES TO HEAT AND RAISES THE TEMPERATURE OF THE AIR, THE GROUND, AND SURROUNDING OBJECTS. THE INTENSITY OF THE RADIATION RECEIVED ON THE EARTH'S SURFACE INCREASES WITH THE HEIGHT ABOVE SEA LEVEL, BECAUSE LESS IS LOST TO THE ATMOSPHERE.


REFLECTION FROM CLOUDS
ABSORPTION
REFLECTION FROM GROUND
DIFFUSE SCATTERING
TO THE GROUND

SOLAR RADIATION

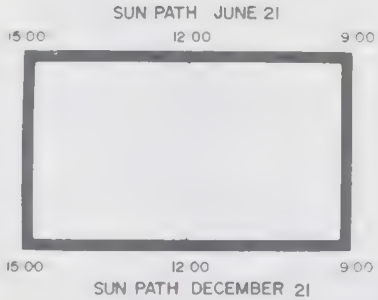
PERCENTAGE OF SOLAR RADIATION REFLECTED

NATURE OF SURFACE	PERCENTAGE OF REFLECTION
GROUND, DRY	[illegible] 25
GROUND, WET	[illegible] 9
SAND, DRY	8 - 30
SAND, WET	[illegible] - 6
ROCK	[illegible] 5
GLASS	32
GREEN GRASS	[illegible] 6
GREEN LEAVES	[illegible] – 32
BRICKS	23 – 48
ASPHALT	[illegible]
CITY AREA	[illegible]
SNOW [illegible]	[illegible]
WATER POOL [illegible]	90 %

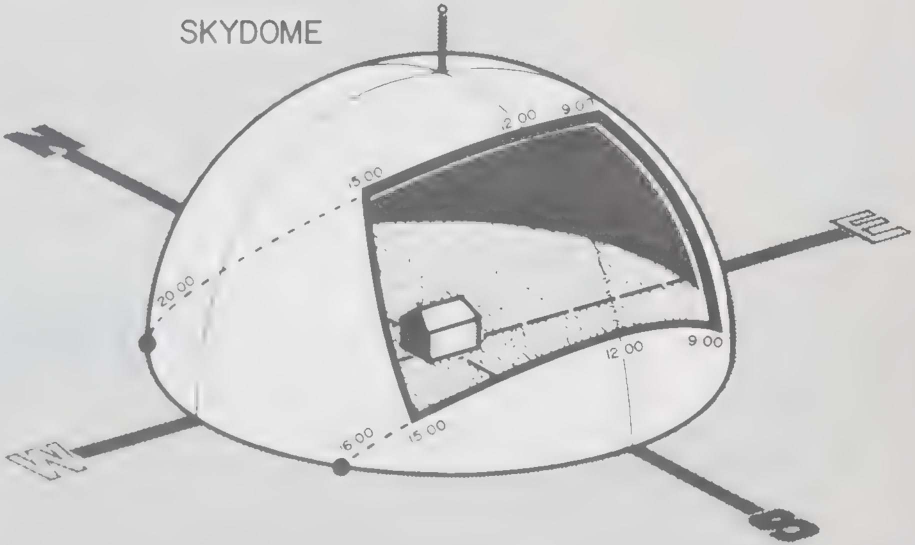


REFLECTION OF SOLAR RADIATION

SUN WINDOW


SUN PATH JUNE 21
15 00
12 00
9 00
15 00
12 00
9 00
SUN PATH DECEMBER 21

THE SUN WINDOW IS AN OPENING CUT IN AN IMAGINARY SKYDOME. ANY OBSTRUCTION BY A NATURAL OR MAN-MADE OBJECT COULD MAKE AN ACTIVE AND / OR PASSIVE SOLAR SYSTEM INEFFECTIVE. THE SUN WINDOW IS A PHYSICAL REPRESENTATION OF "THE RIGHT TO SUN LIGHT".

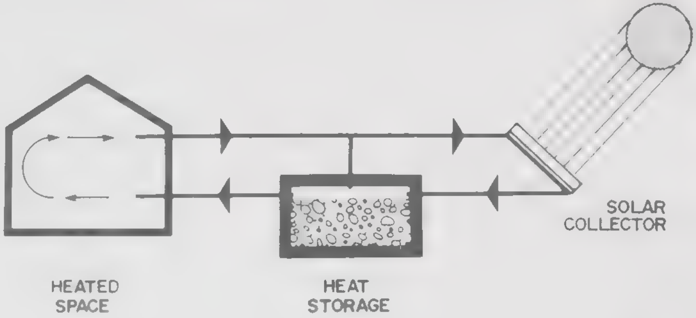

SKYDOME
12 00
9 00
15 00
20 00
16 00
15 00
12 00
9 00
N
E
W
S

ACTIVE SOLAR ENERGY SYSTEMS ARE VERY SOPHISTICATED MECHANICAL SYSTEMS. THEIR LONG RANGE FUTURE IS UNDOUBTEDLY VERY PROMISING.

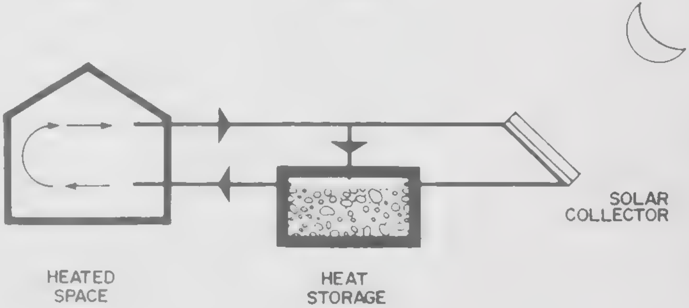
AT PRESENT, THE ECONOMY OF AN ACTIVE SOLAR SYSTEM HAS TO BE MEASURED BY LIFE-CYCLE COSTING. THE INITIAL CAPITAL EXPENDITURE IS USUALLY HIGH.

SOLAR — ACTIVE

AN ACTIVE SOLAR SYSTEM IS A DEVICE USED TO TRANSFORM SOLAR RADIATION TO USABLE HEAT ENERGY ACCUMULATED IN THE COLLECTOR IS TRANSFERRED BY AIR, WATER, OR OTHER FLUIDS TO THE PLACE WHERE IT IS USED, OR TO THE PLACE WHERE IT IS STORED FOR FUTURE USE THE MOST COMMON FORM OF ACTIVE COLLECTOR IS KNOWN AS A "FLAT-PLATE COLLECTOR" WHICH IS MERELY AN INSULATED BOX WITH A GLASS COVER AND AN ABSORBER PLATE SOLAR RADIATION ENTERING THE GLASS COVER IS CAPTURED BY THE PLATE. A FLUID IS CIRCULATED THROUGH OR OVER THE PLATE TO REMOVE THE HEAT FROM THE COLLECTOR TO ITS POINT OF USE

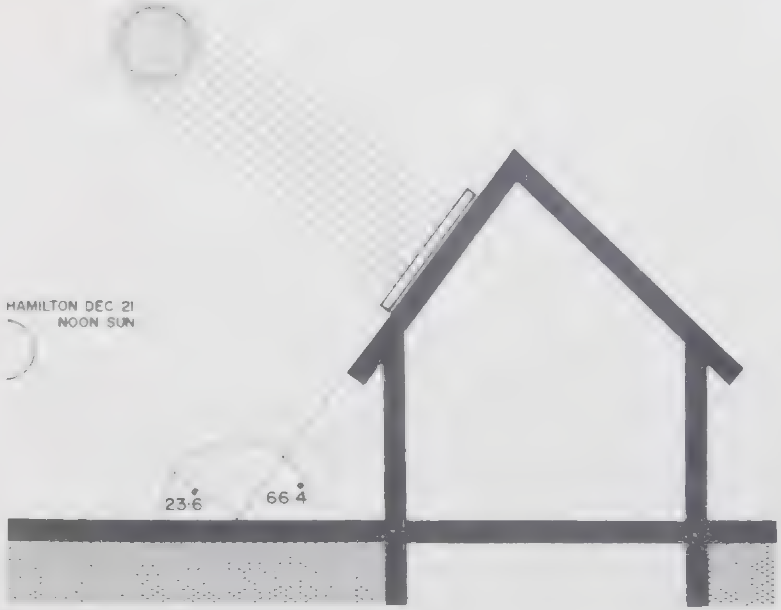


THERE ARE SOME OTHER TYPES OF COLLECTORS USED IN ACTIVE SYSTEMS A COLLECTOR CAN BE MOUNTED SO THAT IT FOLLOWS THE PATH OF THE SUN ACROSS THE SKY THIS INCREASES ITS ABILITY TO CAPTURE SOLAR RADIATION. SUCH TYPES OF SYSTEMS ARE KNOWN AS "TRACKING COLLECTORS." REFLECTORS AND LENSES CAN BE USED TO INCREASE THE SOLAR RADIATION REACHING THE ABSORBER PLATE THESE ARE KNOWN AS "CONCENTRATING COLLECTORS" AND, LIKE TRACKING COLLECTORS, GENERATE HIGHER TEMPERATURES THAN STATIONARY FLAT-PLATE COLLECTORS YET ANOTHER KIND OF COLLECTOR, THE "EVACUATED TUBE" SYSTEM, USES A VACUUM BETWEEN VARIOUS GLASS TUBES NESTED WITHIN ONE ANOTHER TO REDUCE HEAT LOSSES THESE COLLECTORS OPERATE AT HIGHER EFFICIENCIES AND TEMPERATURES THAN FLAT-PLATE COLLECTORS



CURRENTLY MARKETED ACTIVE SOLAR SYSTEMS ARE RAPIDLY IMPROVING IN PERFORMANCE AND RELIABILITY. BEFORE INCORPORATING AN ACTIVE SOLAR SYSTEM INTO YOUR DEVELOPMENT, CONSULT SEVERAL REPUTABLE MANUFACTURERS AND COMPARE

ACTIVE SOLAR ENERGY SYSTEM


HAMILTON DEC 21
NOON SUN
23·6°
66·4°

FOR THE BEST WINTER SUN ENERGY HARVEST, THE USUALLY RECOMMENDED SOLAR COLLECTOR ANGLE IS 60 DEGREES

SOLAR COLLECTOR ANGLE

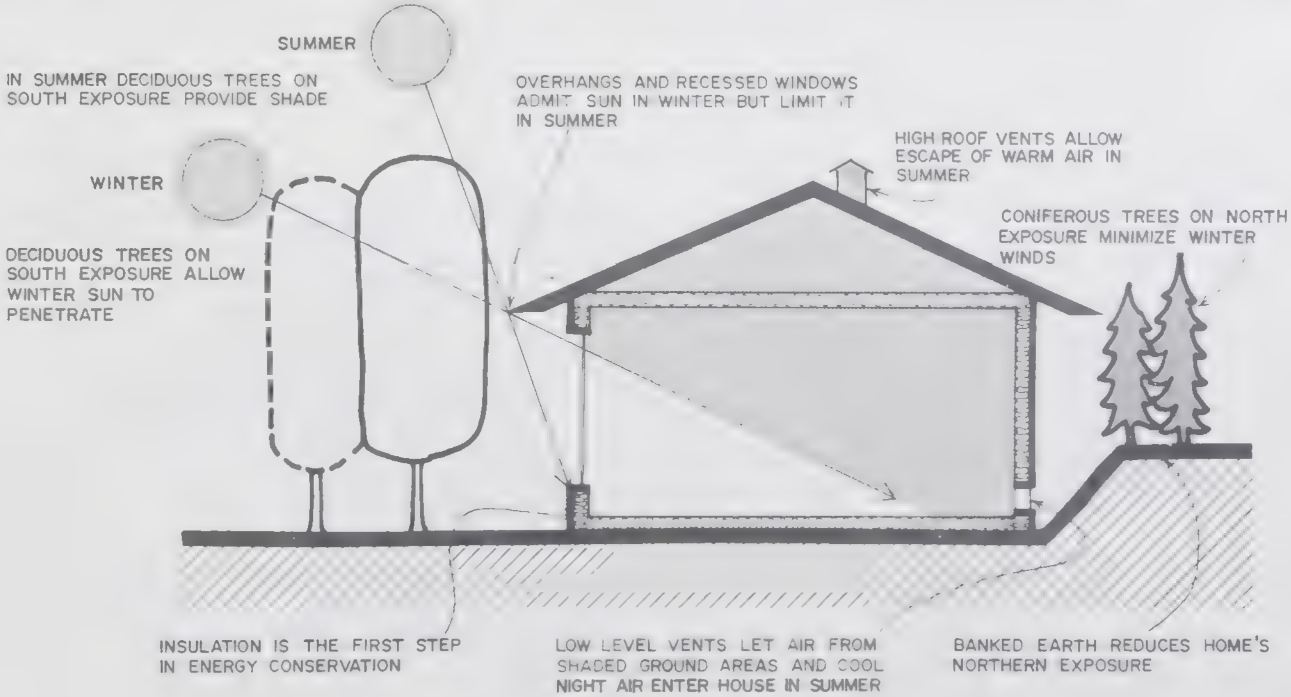
THE PASSIVE SOLAR SYSTEM IS ONE OF MANY APPROACHES TO GREATER ENERGY EFFICIENCY IN URBAN AND REGIONAL PLANNING, AND IN ARCHITECTURAL DESIGN. ALTHOUGH THIS APPROACH IS AS OLD AS MANKIND, MOST OF THE KNOWLEDGE RELATED TO IT HAS DISAPPEARED WITHOUT A TRACE DURING THE LAST SEVERAL DECADES. THUS, SKILLS MUST BE RE-LEARNED AND IDEAS RE-INVENTED. WE ARE IN THE MIDST OF A RENAISSANCE PROCESS.

THE BASIC AIM OF THE PASSIVE SOLAR APPROACH OR SOFT PATH IS TO ACHIEVE HIGH ENERGY EFFICIENCY BY USING SIMPLE, INEXPENSIVE MEANS. IT HAS BEEN ESTABLISHED THAT THIS APPROACH IS DIRECTLY COMPETITIVE WITH A CONVENTIONAL SYSTEM, BOTH IN TERMS OF ECONOMY AND THERMAL COMFORT. THE DIFFICULTY LIES IN THE FACT THAT THE SOFT PATH REQUIRES "FRONT-END INVESTMENT", THE INVESTMENT OF INTELLECTUAL ENERGY.

IN OTHER WORDS, WE CAN ACHIEVE A VERY HIGH LEVEL OF ENERGY EFFICIENCY AND AVOID THE USE OF VERY EXPENSIVE AND VERY COMPLEX TECHNOLOGIES; THE DESIGN, HOWEVER, MUST BE TUNED TO THE

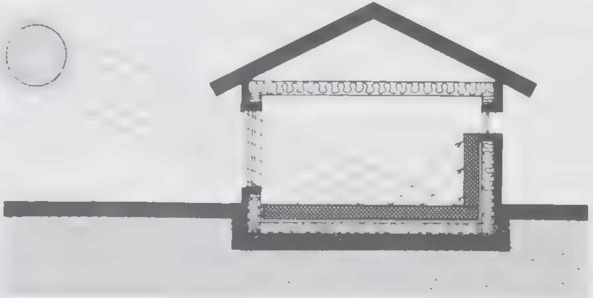
SURROUNDINGS. THE INCORPORATION OF TOPOGRAPHICAL AND CLIMATIC FACTORS CONSTITUTES THE INCORRUPTIBLE PRINCIPLE OF A SOPHISTICATED DESIGN. UNFORTUNATELY, THIS TYPE OF SOPHISTICATION HAS NEVER BEEN PART OF OUR TRADITION.

NOW IS THE TIME TO ESTABLISH SUCH A TRADITION.


SUMMER
IN SUMMER DECIDUOUS TREES ON SOUTH EXPOSURE PROVIDE SHADE
WINTER
DECIDUOUS TREES ON SOUTH EXPOSURE ALLOW WINTER SUN TO PENETRATE
OVERHANGS AND RECESSED WINDOWS ADMIT SUN IN WINTER BUT LIMIT IT IN SUMMER
HIGH ROOF VENTS ALLOW ESCAPE OF WARM AIR IN SUMMER
CONIFEROUS TREES ON NORTH EXPOSURE MINIMIZE WINTER WINDS
INSULATION IS THE FIRST STEP IN ENERGY CONSERVATION
LOW LEVEL VENTS LET AIR FROM SHADED GROUND AREAS AND COOL NIGHT AIR ENTER HOUSE IN SUMMER
BANKED EARTH REDUCES HOME'S NORTHERN EXPOSURE

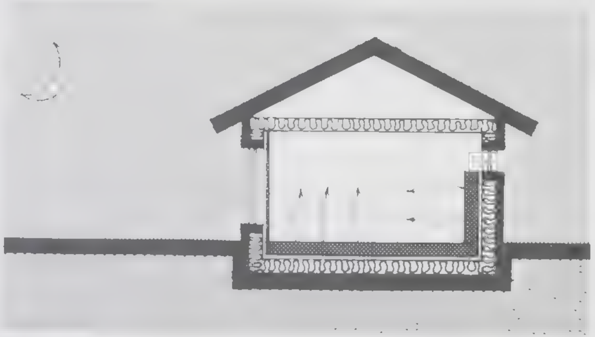
ELEMENTS OF A PASSIVE SOLAR SYSTEM

IN THE DAY, THE SUN'S RADIATION PASSES THROUGH THE SOUTH — FACING GLASS, ABSORBED AND STORED BY THE MASS OF THE HOUSE (CONCRETE FLOOR AND WALLS)



DAY

AT NIGHT AN INSULATED SHUTTER CLOSES THE GLASS AND PROTECTS AGAINST HEAT LOSS. HEAT RADIATES WITHIN

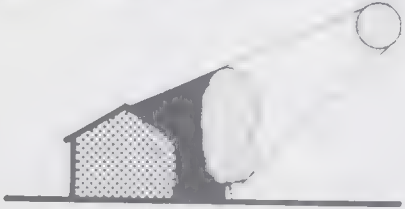


NIGHT

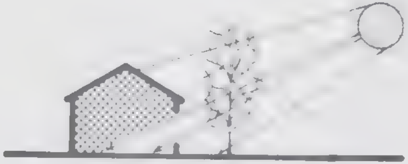
THE MECHANICS OF A PASSIVE SOLAR SYSTEM

DECIDUOUS TREES PLANTED ON THE SOUTH AND WEST SIDES OF A BUILDING PROVIDE :

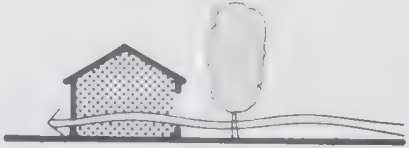
COOLING SHADE IN SUMMER



SUNLIGHT IN WINTER

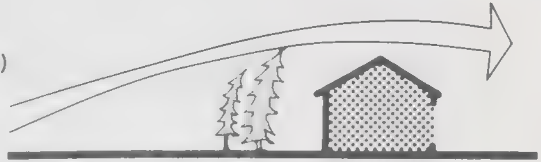


COOLING SUMMER BREEZE

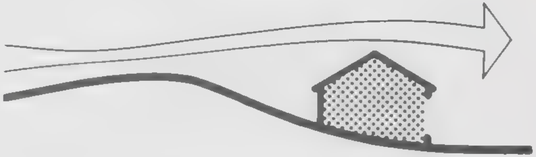


PASSIVE SOLAR DESIGN PRINCIPLES

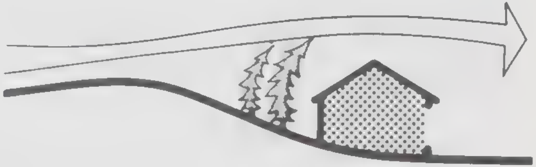
CONIFEROUS TREES (EVERGREEN) PLANTED ON THE NORTH AND WEST SIDES OF A BUILDING PROTECT FROM WINTER WINDS



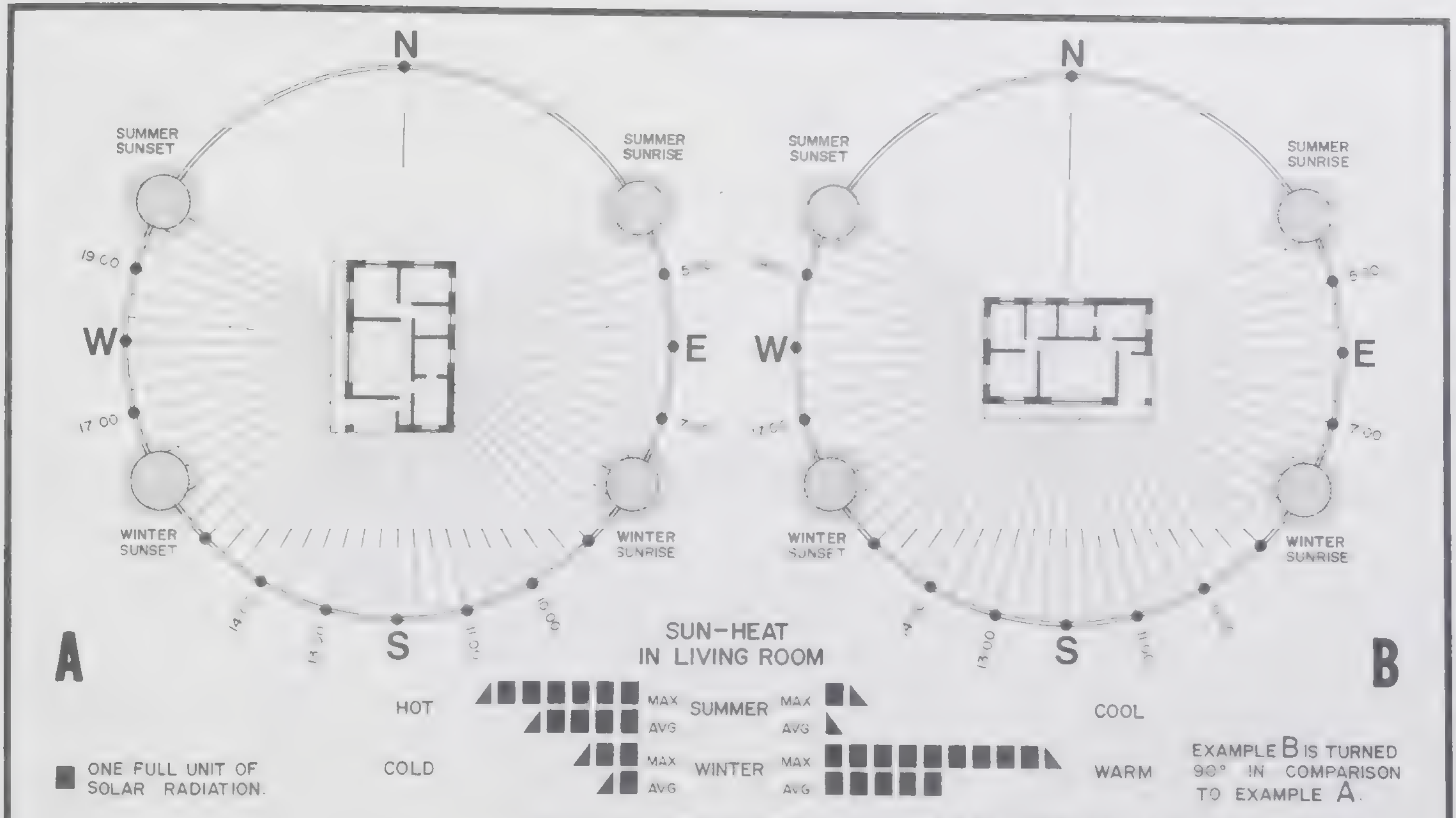
LAND FORM DEFLECTS WINTER WINDS



EVERGREEN TREES PROVIDE ADDITIONAL PROTECTION



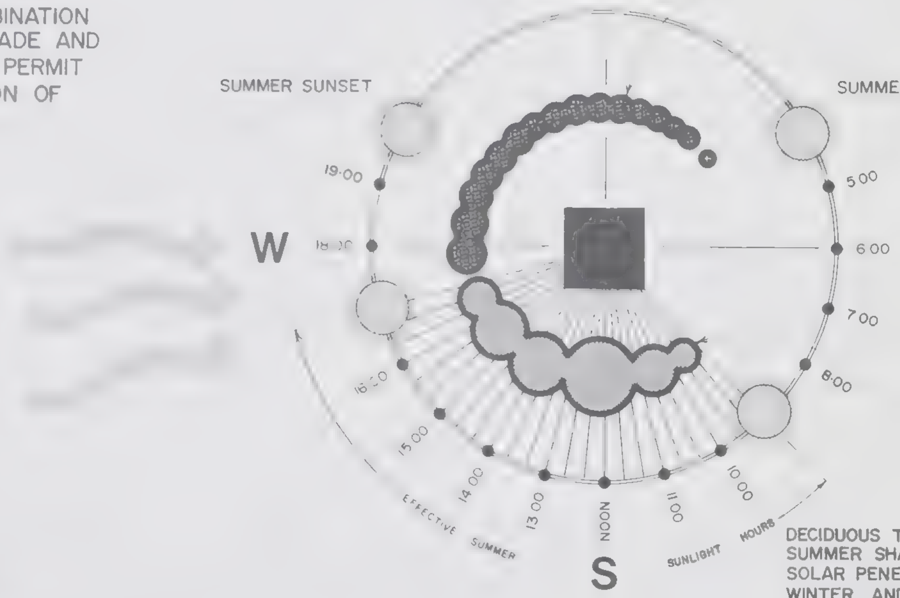
PASSIVE SOLAR DESIGN PRINCIPLES


N
SUMMER SUNSET
SUMMER SUNRISE
19 00
5 00
W
E
17 00
7 00
WINTER SUNSET
WINTER SUNRISE
14 00
13 00
S
11 00
10 00
A
N
SUMMER SUNSET
SUMMER SUNRISE
5 00
W
E
17 00
7 00
WINTER SUNSET
WINTER SUNRISE
14
13 00
S
11 00
B
SUN-HEAT IN LIVING ROOM
HOT
MAX
AVG
SUMMER
MAX
AVG
COOL
COLD
MAX
AVG
WINTER
MAX
AVG
WARM
ONE FULL UNIT OF SOLAR RADIATION.

EXAMPLE B IS TURNED 90° IN COMPARISON TO EXAMPLE A.

HOUSE ORIENTATION AND THERMAL COMFORT

CONIFEROUS AND DECIDUOUS TREES SERVE IN MODERATING THE PREVAILING CLIMATE OF A SITE. THEY CAN BE USED EFFECTIVELY IN COMBINATION BOTH TO PROVIDE SHADE AND WINDBREAKS AND TO PERMIT MAXIMUM PENETRATION OF SUNLIGHT.


N
E
S
W
SUMMER SUNSET
SUMMER SUNRISE
19·00
18·00
16·00
15·00
14·00
13·00
NOON
11·00
10·00
8·00
7·00
6·00
5·00
EFFECTIVE SUMMER SUNLIGHT HOURS

INCIDENTAL WINTER STORMS

CONIFEROUS TREES TO CONTROL WINDS AND PRIVACY

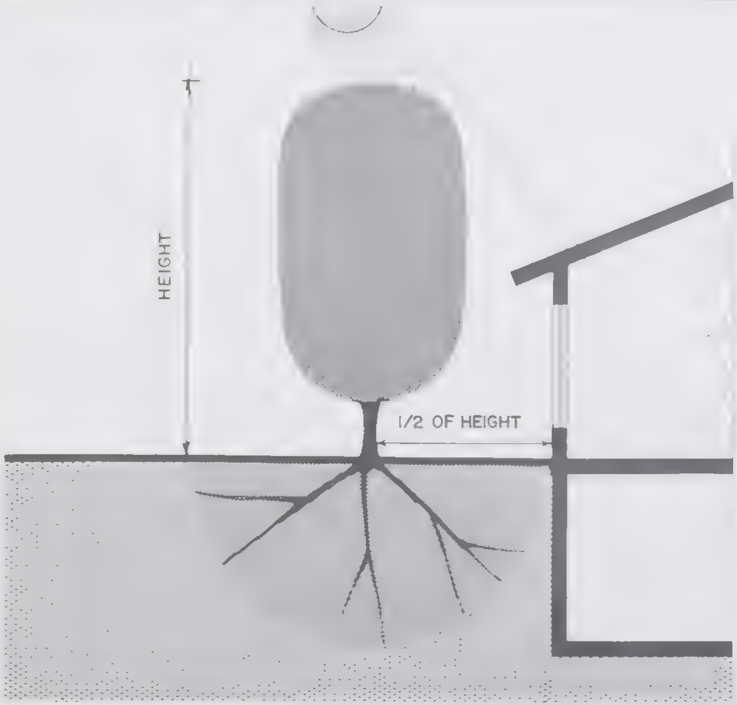
PREVAILING WINTER WIND DIRECTION

DECIDUOUS TREES TO PROVIDE SUMMER SHADE AND ALLOW SOLAR PENETRATION IN FALL, WINTER, AND SPRING

HAMILTON AREA

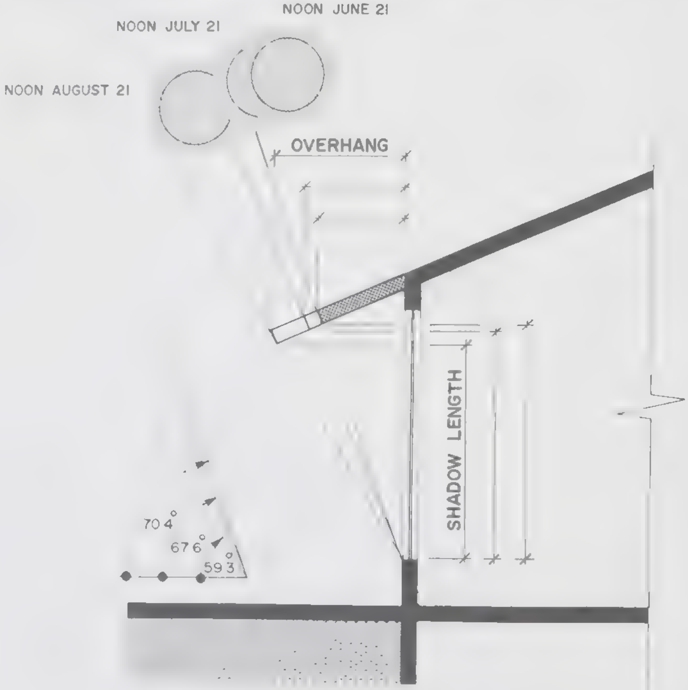
SOLAR LANDSCAPING

ALL TREES SHOULD BE PLANTED AT A SUFFICIENT DISTANCE FROM THE STRUCTURE SO THAT THEIR ROOT SYSTEM DOES NOT INTERFERE WITH THE BUILDING FOUNDATIONS. MOST TREES EXTRACT A CONSIDERABLE AMOUNT OF MOISTURE FROM THE SOIL, AND EXCESSIVE DEHYDRATION CAN CAUSE DIFFERENTIAL SETTLEMENT OF BELOW-GROUND CONSTRUCTION. **A RELIABLE RULE OF THUMB FOR DECIDUOUS TREES IS THAT THE ROOT SYSTEM WILL EXTEND RADIALLY TO A DISTANCE EQUAL TO AT LEAST HALF THE HEIGHT OF THE TREE** THUS, ANY TREE SHOULD BE PLACED NO CLOSER THAN THE EXPECTED EXTENT OF ITS ROOT SYSTEM AT FULL MATURITY.



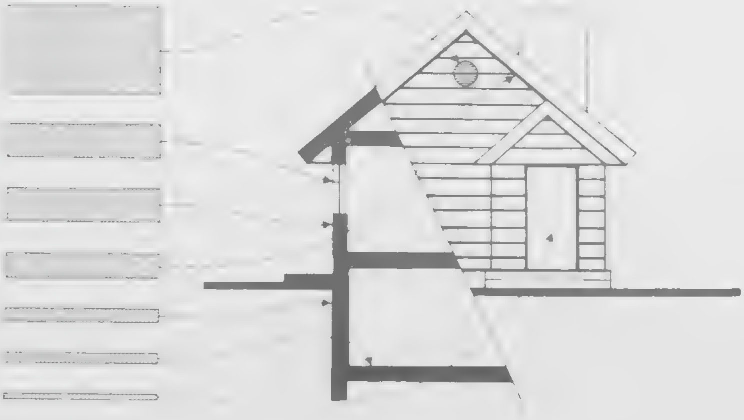
SOLAR LANDSCAPING

THE OVERHANG IS THE MOST EFFECTIVE METHOD FOR SHADING SOUTH-FACING GLASS IN SUMMER THIS SHADING DEVICE IS SIMPLY A ROOF PROJECTION. THE OPTIMUM PROJECTION OF THE OVERHANG FROM THE FACE OF THE BUILDING IS DEPENDENT UPON WINDOW HEIGHT, LATITUDE AND CLIMATE


NOON JUNE 21
NOON JULY 21
NOON AUGUST 21
OVERHANG
SHADOW LENGTH
70.4°
67.6°
59.3°

OVERHANG

VENTILATION AND INFILTRATION	42 %
WINDOWS	16 %
WALLS ABOVE GRADE	16 %
ROOF AND CEILING	12 %
WALLS BELOW GRADE	6 %
BASEMENT FLOOR	5 %
DOORS	3 %



THE HEAT LOSS DISTRIBUTION TABLE INDICATES THAT AN EFFICIENTLY PERFORMING ENERGY CONSERVATION HOUSE WOULD REQUIRE THE FOLLOWING

- PROPERLY CALCULATED AND INSTALLED INSULATION
- AIR EXCHANGE CONTROL
- EXCELLENT CRAFTSMANSHIP
- SELECTED WINDOWS AND ENTRANCE DESIGNS
- A HEAT RECOVERY SYSTEM

HEAT LOSS

EVEN IN HAMILTON'S LATITUDE, A FULL UTILIZATION OF THE DESIGN PRINCIPLES OF A PASSIVE SOLAR SYSTEM AND A SOFT TECHNOLOGY APPROACH WOULD MAKE POSSIBLE THE COMPLETE ELIMINATION OF A CONVENTIONAL HEATING SYSTEM. THUS, THE ANNUAL HEATING BILL COULD EQUAL ZERO.

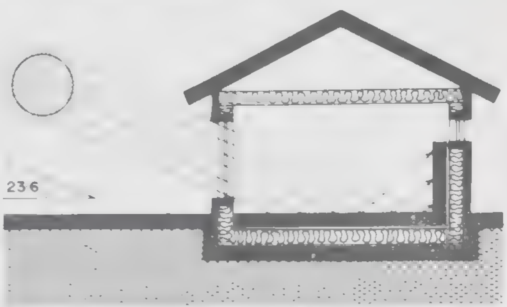
HOWEVER, A GREAT DEAL OF METICULOUS PLANNING AND DESIGN IS NECESSARY BEFORE THE COMMENCEMENT OF DIGGING. THE TIME AND MONEY SPENT ON PLANNING AND DESIGN IS THE WISEST INVESTMENT.

OBVIOUSLY, THIS APPROACH WILL REQUIRE A SIGNIFICANT CHANGE IN ATTITUDE ON THE PART OF THE CONSTRUCTION INDUSTRY.

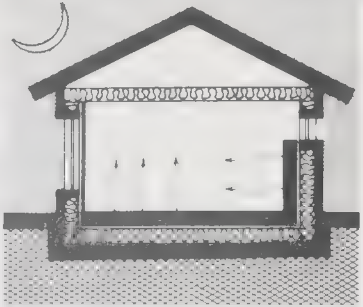
THE FOLLOWING IS A BRIEF REVIEW OF THE MOST COMMON CURRENT PASSIVE SOLAR SYSTEMS.

IN THE HEATING SEASON, SOUTH-FACING GLAZED WINDOWS ARE NET GAINERS OF SOLAR RADIATION. IN FACT, A SOUTH-FACING WINDOW CONSERVES MORE HEATING ENERGY OVER THE LONG TERM THAN ANY AMOUNT OF WALL INSULATION

FURTHERMORE, PROVIDE THERMAL SHUTTERS AND BLINDS OR MOVABLE WINDOW INSULATION IN ORDER TO REDUCE OUTWARD HEAT LOSSES AT NIGHT

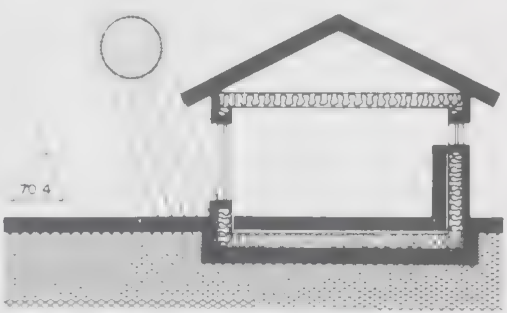


HAMILTON DECEMBER 21 ALTITUDE 23.6° WINTER DAY

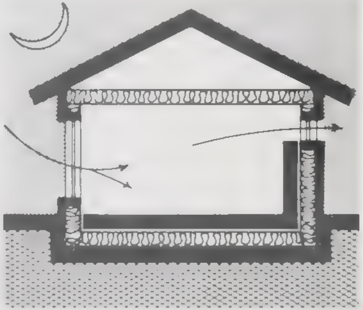


WINTER NIGHT

IN SUMMER, THE HOUSE CAN BE PROTECTED FROM SOLAR RADIATION BY THE USE OF OVERHANGS, VERTICAL LOUVERS AND EVEN DECIDUOUS TREES.



HAMILTON JUNE 21 ALTITUDE 70.4° SUMMER DAY



SUMMER NIGHT

DIRECT PASSIVE GAIN

INDIRECT PASSIVE GAIN

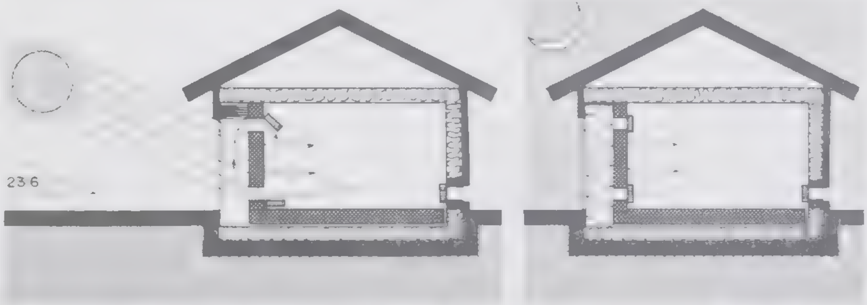
MASS WALLS

TWO TYPES OF INDIRECT GAIN MASS WALL PASSIVE SYSTEMS ARE IN USE

- WATERWALL: ACTS AS THE HEAT SYSTEM ELEMENT;
- TROMBE WALL: IS A CONCRETE OR SOLID MASONARY WALL SERVING AS THE HEAT STORAGE ELEMENT

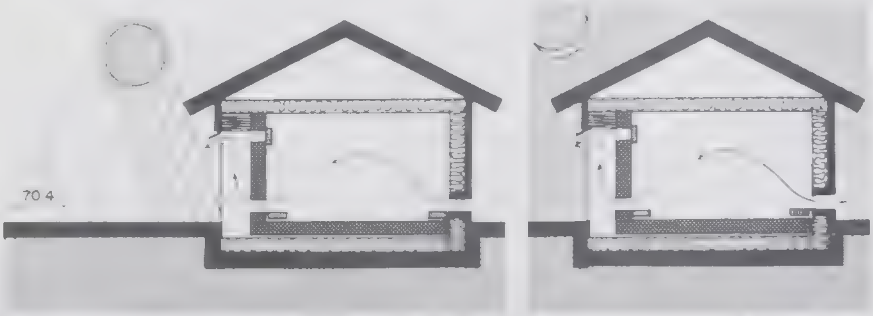
BOTH MASS SYSTEMS ARE POSITIONED BEHIND VERTICAL SOUTH—FACING GLAZING

THE AIR BETWEEN THE GLAZING AND THE VERTICAL MASS BECOMES HEATED IT IS POSSIBLE TO NATURALLY CONVECT THIS AIR TO THE HEATED SPACE BY THE PROVISION OF DAMPERS AT THE TOP AND BOTTOM OF THE MASS STORAGE WALL



HAMILTON DECEMBER 21 ALTITUDE 23.6° WINTER DAY WINTER NIGHT

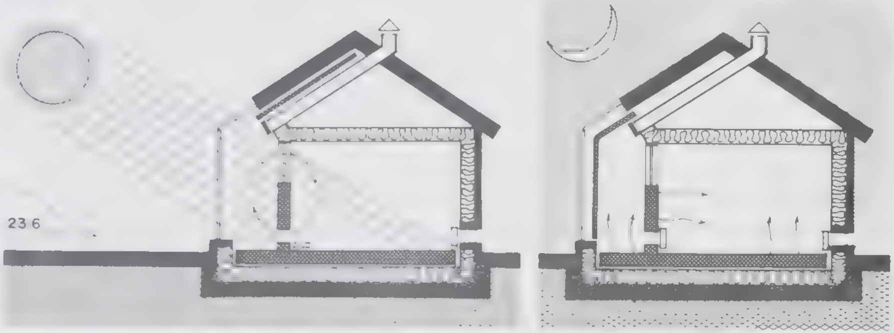
IN THE SUMMER, BY CLOSING THE DAMPER AT THE TOP OF THE WALL AND OPENING ONE TO THE EXTERIOR, IT IS POSSIBLE TO USE THE SAME CONVECTIVE FLOW TO DRAW AIR INTO THE BUILDING THROUGH A DAMPER ON THE NORTH SIDE AND THEREFORE CONVECTIVELY COOL THE BUILDING.



HAMILTON JUNE 21 ALTITUDE 70.4° SUMMER DAY SUMMER NIGHT

SOLAR RADIATION IS ADMITTED INTO THE BUILDING BY SOUTH-FACING WINDOWS AND SKYLIGHTS THE SPACES DIRECTLY HEATED ARE ANCILLARY ARCHITECTURAL SPACES SUCH AS GREEN HOUSES, ATRIA, SUNROOMS, ETC. WHICH ARE ATTACHED TO THE PRINCIPAL LIVING SPACES

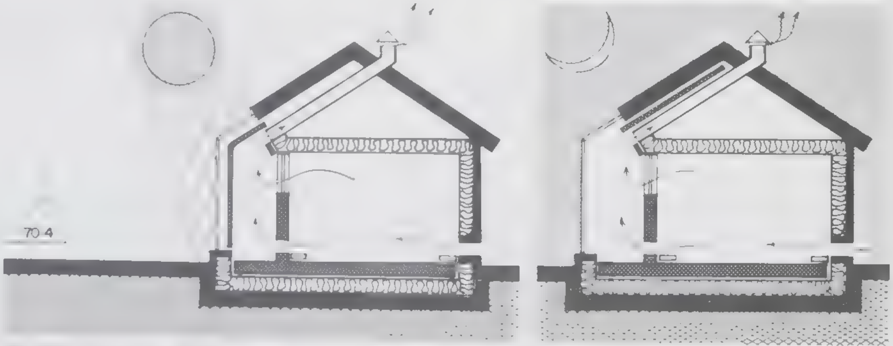
SOLAR RADIATION MAY BE DIRECTLY TRANSMITTED FROM THE SUNSPACE TO THE LIVING SPACE BY GLAZING. DOORS OR DAMPERS MAY BE OPENED TO PERMIT NATURAL CONVECTIVE HEAT FLOW WITHIN THE PRIME LIVING SPACES



HAMILTON DECEMBER 21 ALTITUDE 23.6° WINTER DAY

WINTER NIGHT

IN THE SUMMER, A SUNSPACE MAY BE USED TO CONVECTIVELY COOL THE LIVING SPACE OF A BUILDING BY OPERATING A VENT TO THE OUTDOORS FROM THE TOP OF THE SUNSPACE. COOL AIR IS THEN DRAWN THROUGH THE LIVING SPACE TO REPLACE HEATED AIR CONVECTED OUT OF THE SUNSPACE



HAMILTON JUNE 21 ALTITUDE 70.4° SUMMER DAY

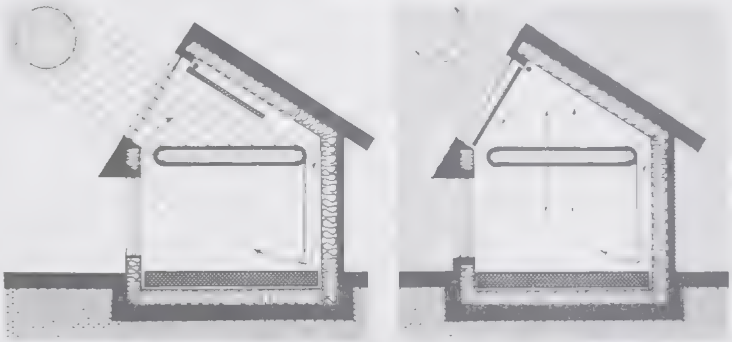
SUMMER NIGHT

SUNSPACE SYSTEM

MASS ROOF SYSTEMS ARE ALSO CALLED ROOF PONDS

THEY CONSIST OF A POND OF WATER ENCLOSED IN DARK PLASTIC WHICH IS PLACED UPON METAL CEILINGS A SHUTTER SYSTEM IS INSTALLED ABOVE.

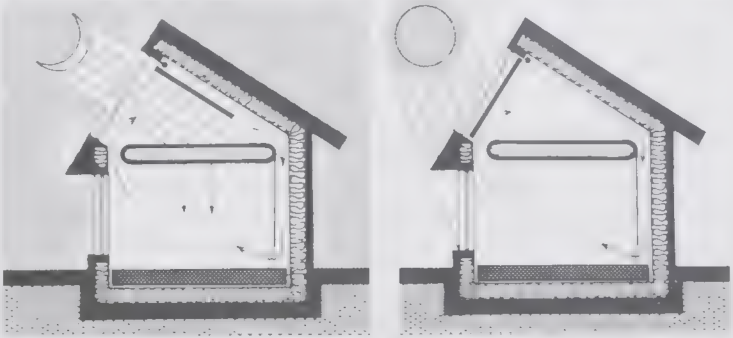
IN THE WINTER, THE SHUTTERS ARE OPENED DURING THE DAY TO ABSORB SOLAR RADIATION WITHIN THE ROOF POND. AT NIGHT, THE SHUTTERS ARE CLOSED AND THE STORED ENERGY IS RADIATED DOWNWARD WITHIN THE HEATED SPACE.



DEC. 21 ALT. 23·6° WINTER DAY

WINTER NIGHT

IN THE SUMMER, THE SHUTTERS ARE OPENED AT NIGHT AND THE ROOF POND IS COOLED DURING THE DAYTIME, THE SHUTTERS ARE CLOSED AND THE POND ABSORBS HEAT FROM WITHIN THE HOUSE KEEPING IT COOL



SUMMER NIGHT

JUNE 21 ALT. 70·4° SUMMER DAY

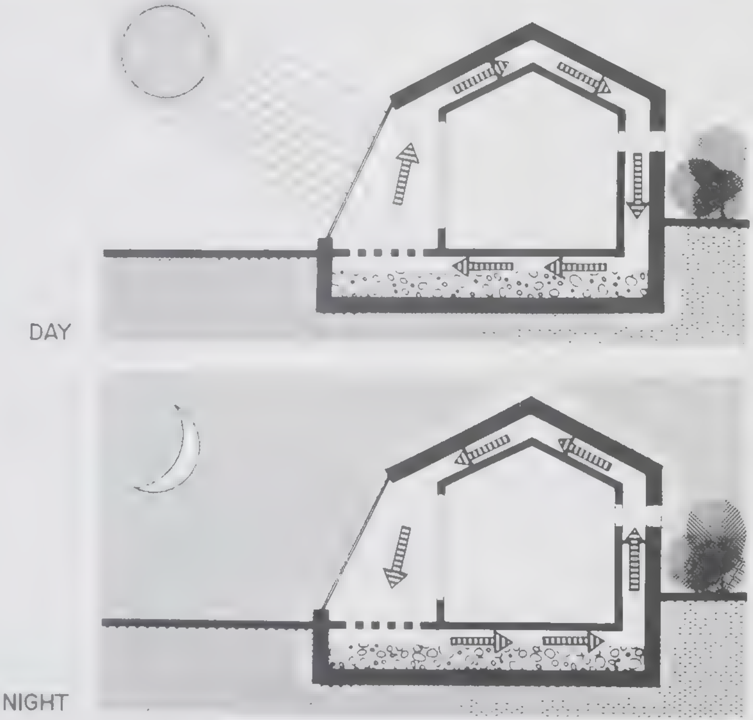
MASS ROOF

THE DOUBLE SHELL CONCEPT IS THE MOST SOPHISTICATED SOLUTION IN THE PASSIVE SOLAR APPROACH

SOME OF THEM FUNCTION WITHOUT THE ASSISTANCE OF ANY MECHANICAL DEVICE SUCH AS FANS, BLOWERS, DAMPERS, MOBILE INSULATION ETC

THIS CONCEPT HAS ATTRACTED THE ATTENTION OF MANY U.S. DESIGNERS AND BUILDERS SEVERAL HOUSES ARE ALSO UNDER CONSTRUCTION IN ONTARIO THEIR PERFORMANCE IS BEING CLOSELY MONITORED

THE RESULTS, WHICH ARE COMING IN, ARE STARTLING



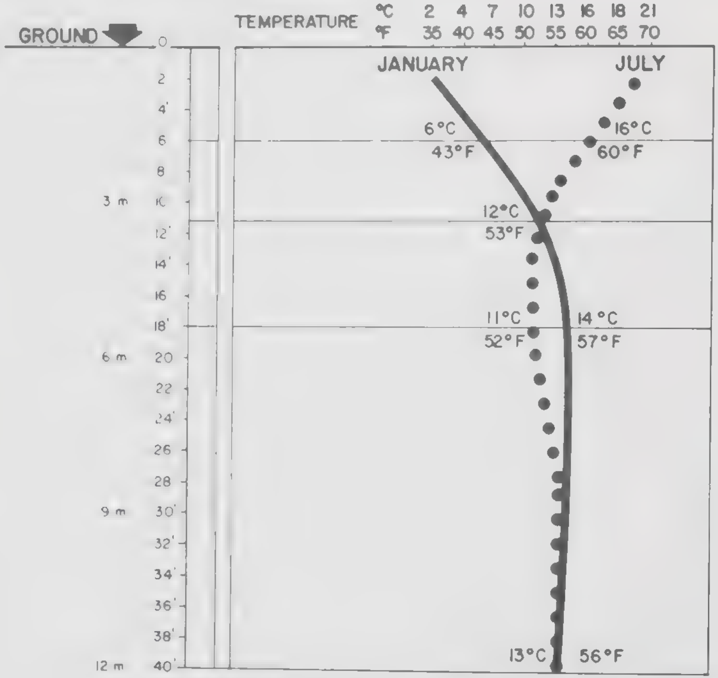
DOUBLE SHELL DESIGN CONCEPT

THOUSANDS OF EARTH-SHELTERED HOUSES HAVE ALREADY BEEN BUILT IN THE U.S.A. ENTHUSIAMS FOR THEM IS SPREADING ACROSS THE BORDER.

ALTHOUGH AN EARTH-SHELTERED HOUSE MAY BE CONSIDERED AN EXTREME SOLUTION TO THE PROBLEM OF AN ENERGY-EFFICIENT HOUSE, THOSE WHO HAVE HAD THE OPPORTUNITY TO VISIT ONE ARE USUALLY ASTONISHED BY THE AMOUNT OF DAYLIGHT, SPATIAL QUALITY AND SUPERIOR THERMAL PERFORMANCE THEY OFFER.

MANY SKEPTICS HAVE BEEN CONVERTED TO VIGOROUS PROMOTERS.

SOIL INSULATION PROPERTIES PEND ON A NUMBER OF FACTORS PHYSICAL AND CHEMICAL COMPOSITION, BIOLOGICAL, CONTENT, MOISTURE, NATURE OF THE SURFACE, ETC IN THE HAMILTON AREA, IT REQUIRES ABOUT THREE TO THREE AND HALF FEET OF EARTH COVER TO PREVENT WATER FROM FREEZING EARTH'S MOST FASCINATING PROPERTY IS ITS LAZY RESPONSE TO TEMPERATURE CHANGES. AS ILLUSTRATED BY THE DIAGRAM, AT A DEPTH OF 18' ANNUAL EXTREMES OF HEAT AND COLD ARE EXACTLY OPPOSITE TO THE SITUATION ON THE SURFACE THERE ARE MANY WAYS OF TAKING ADVANTAGE OF THIS PECULIARITY. ONE METHOD IS THE HEAT PUMP

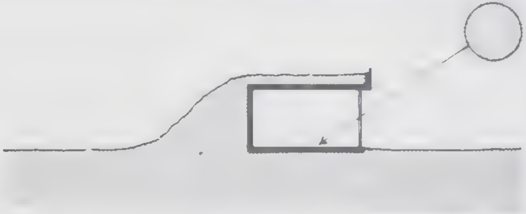


MEASUREMENTS OF THE TEMPERATURE DISTRIBUTION AT THE CAMPUS OF McMASTER UNIVERSITY, HAMILTON, ONTARIO FROM OCTOBER 1964 TO SEPTEMBER 1966

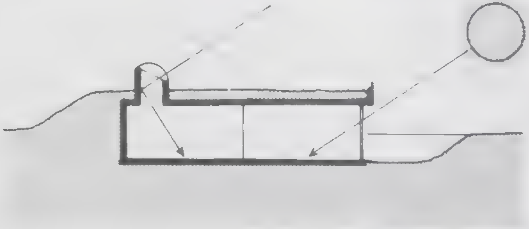
VARIATION OF SOIL TEMPERATURE

FLAT SITE

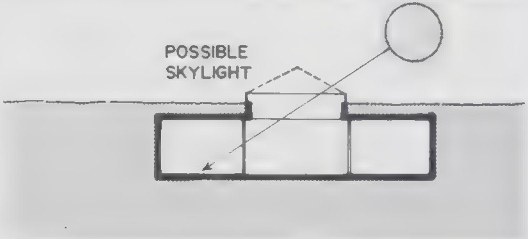
- ABOVE GROUND



- SEMI UNDERGROUND



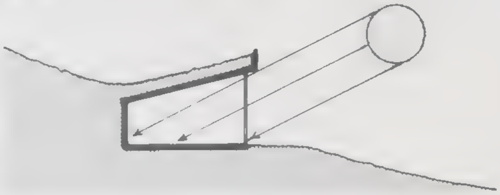
- FULLY UNDERGROUND


POSSIBLE
SKYLIGHT

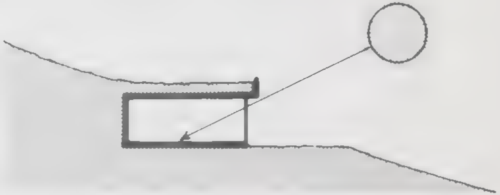
EARTH SHELTERED HOUSES

SLOPING SITE

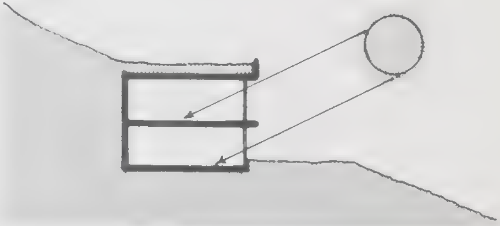
- SLOPING ROOF



- ONE FLOOR



- TWO FLOORS



EARTH SHELTERED HOUSES

During the last few decades, we learned to consider the differences between individual parcels of land of the same size to be marginal. The bulldozer and oversized heating and cooling systems were very successful in the equalization process. While some areas in the current subdivision layout may be suitable for the passive solar approach, the overall planning philosophy is alien to energy conservation. The passive solar approach takes advantage of the topographical and other unique features of an individual site. The street layout, setbacks and height limits are part of a single system which ensures maximum solar exposure. (A guaranteed "sun window" for every house.)

Thus, the most obvious difference between a conventional system and a passive solar approach is in the shape and size of the developable space - the envelope.

A

STREET ORIENTATION : NORTH – SOUTH
LOT AND HOUSE ORIENTATION :
FACING EAST AND FACING WEST

THE SUN IS ONLY AVAILABLE IN THE MORNING OR IN THE EVENING

EACH HOUSE SHADOWS ANOTHER HOUSE

DISADVANTAGES :

- ● ELIMINATES THE POSSIBILITY OF DESIGNING A PASSIVE HEATING SYSTEM
- ● MAKES IMPOSSIBLE THE INSTALLATION OF SOLAR COLLECTORS IN THE FUTURE.
- ● PRIVATE GREEN SPACE IS EXPOSED TO THE SUN FOR HALF A DAY ONLY.

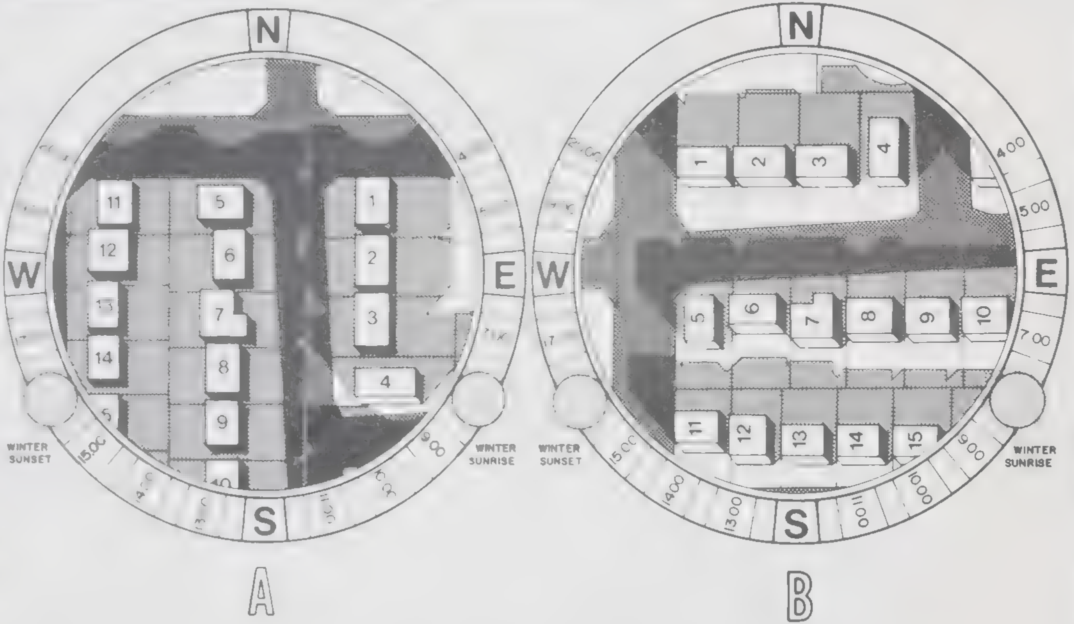
B

THIS IS THE IDENTICAL SUBDIVISION TURNED 90°.

STREET ORIENTATION : EAST – WEST
LOT AND HOUSE ORIENTATION :
FACING NORTH AND FACING SOUTH

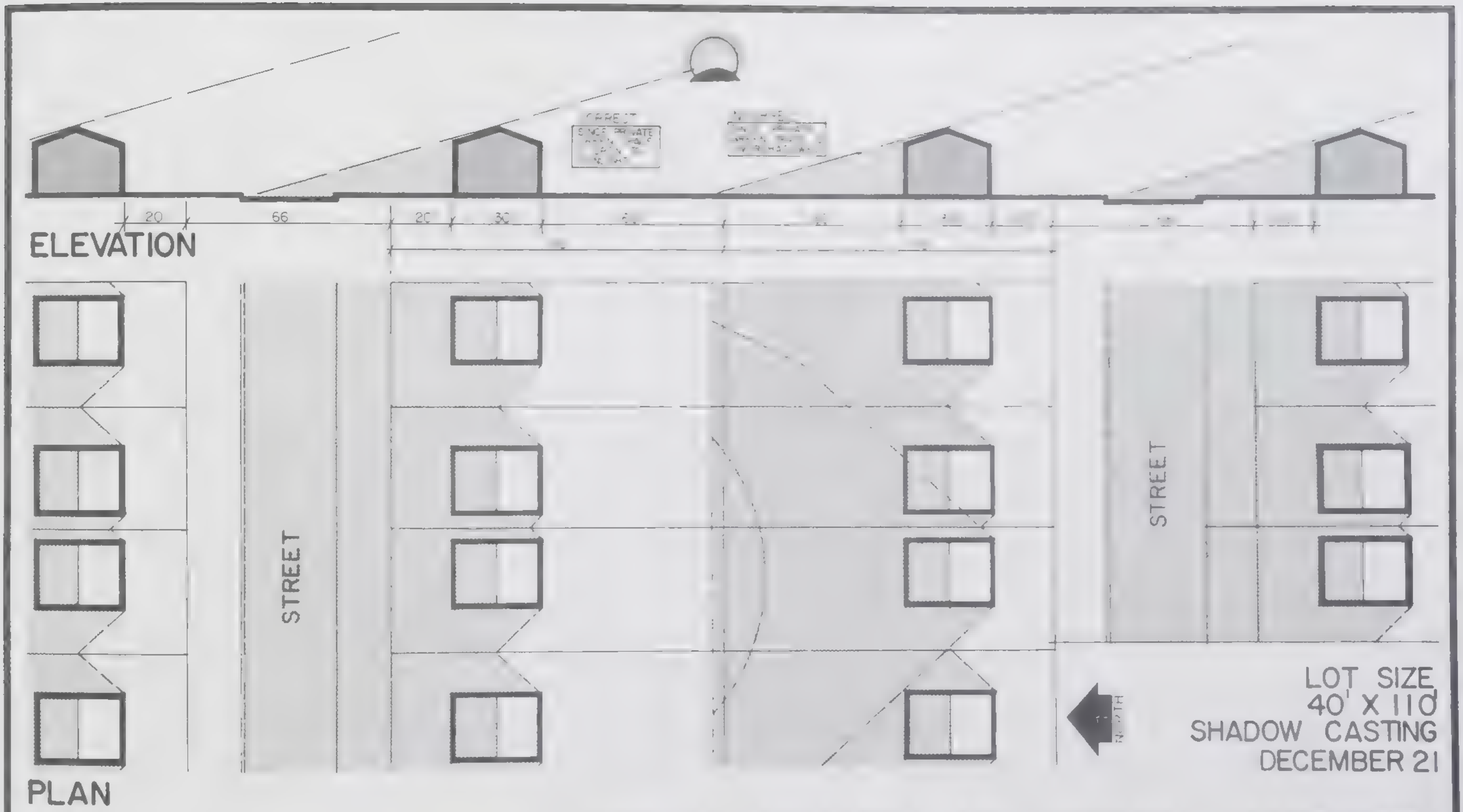
ADVANTAGES :

- ● CONDUCIVE TO THE UTILIZATION OF A PASSIVE SOLAR HEATING SYSTEM
- ● POSSIBILITY OF INSTALLATION OF SOLAR COLLECTORS FOR THE FUTURE
- ● PRIVATE GREEN SPACE EXPOSED TO THE SUN ALMOST THE WHOLE DAY


N
W
E
S
WINTER SUNSET
WINTER SUNRISE
15.00
9.00
11
12
13
14
5
6
7
8
9
10
1
2
3
4
A
N
W
E
S
WINTER SUNSET
WINTER SUNRISE
400
500
700
1500
1400
1300
1100
1000
900
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
B

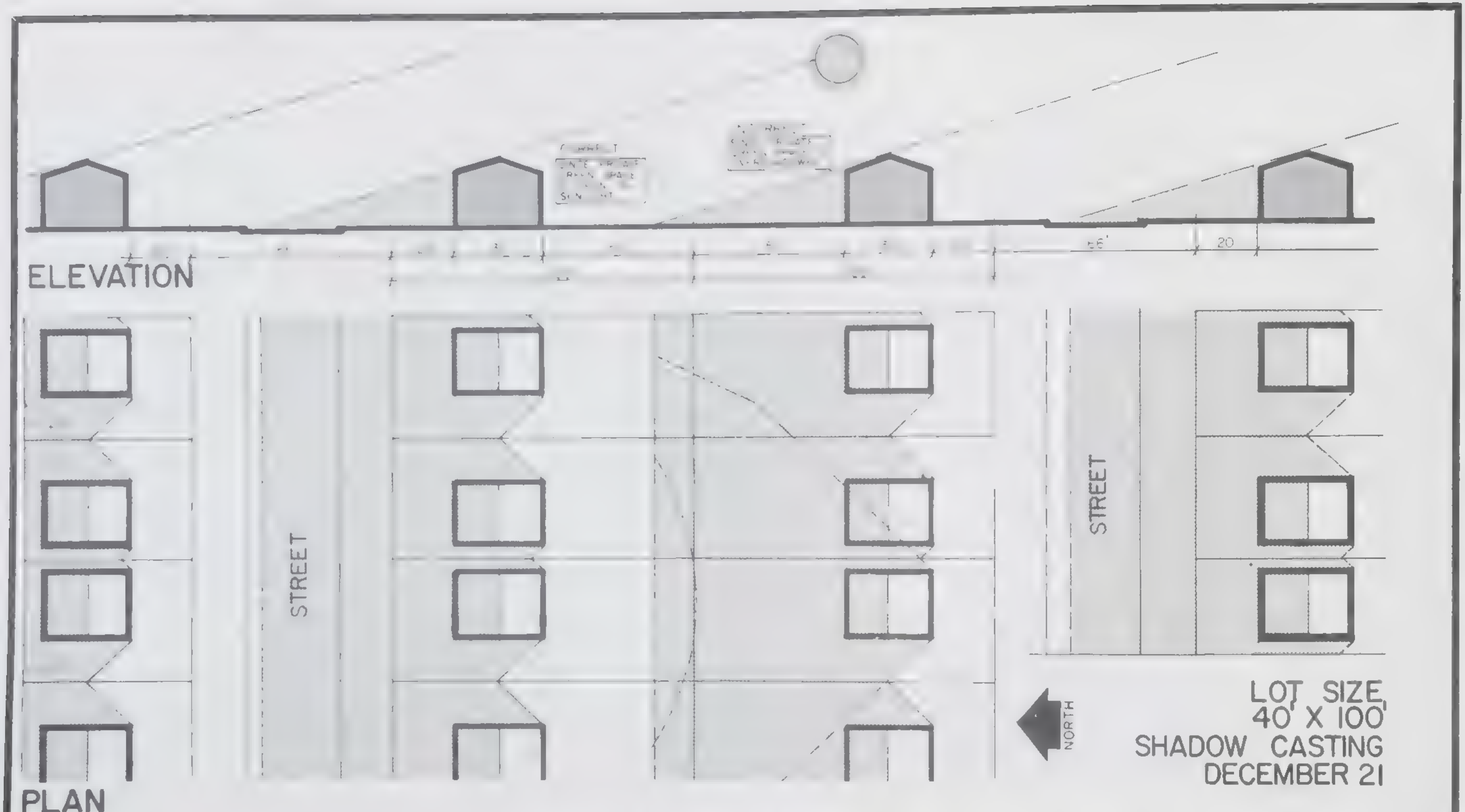
CONCLUSION | SIMPLE 90 DEGREES TURN OF THE SAME SUBDIVISION LAYOUT LEADS TO A HIGH SOLAR ENERGY YIELD AND ENERGY EFFICIENCY

SUBDIVISION ORIENTATION AND SHADOW CASTING


ELEVATION
20
66
20
30
STREET
STREET
PLAN

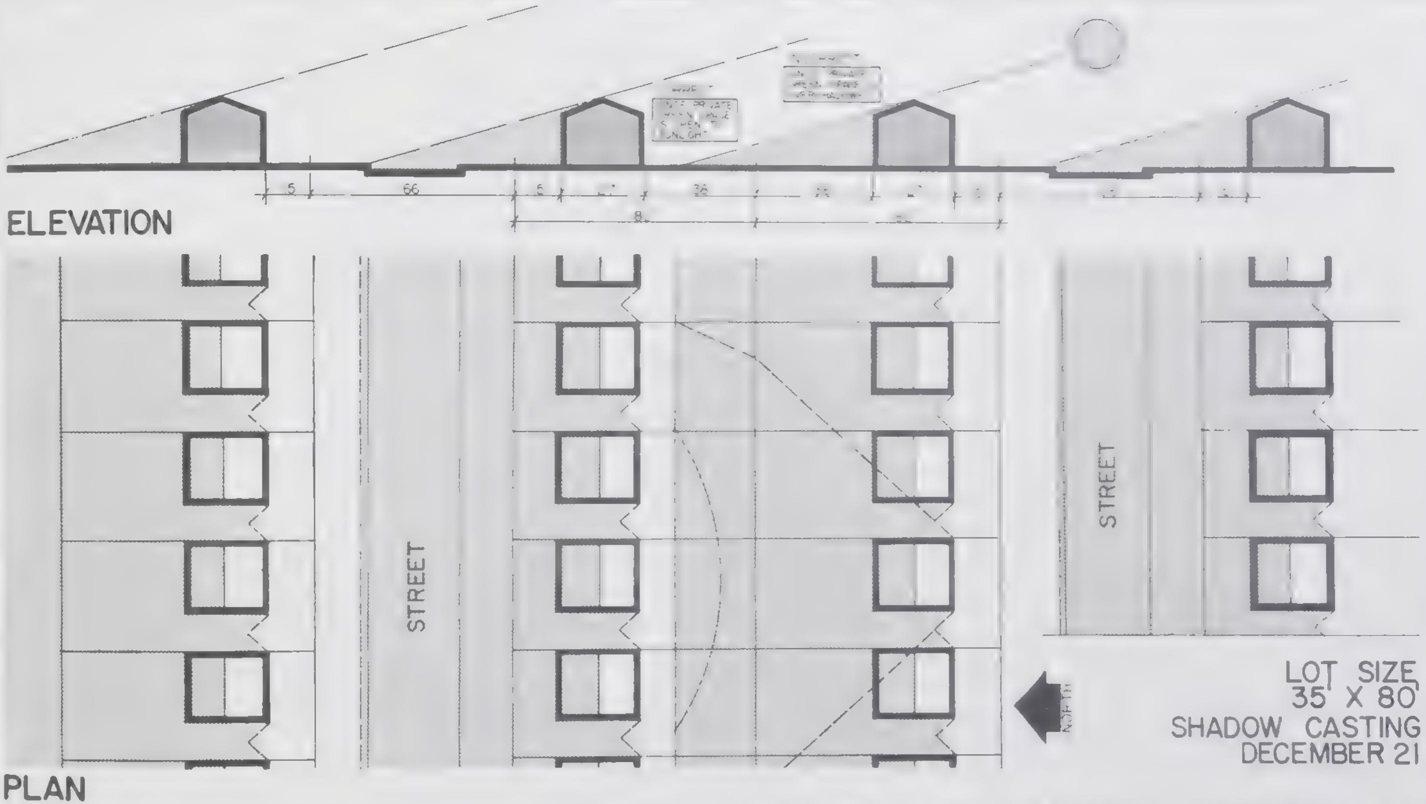
LOT SIZE
40' X 110'
SHADOW CASTING
DECEMBER 21

TYPICAL EXAMPLE OF EXISTING SUBDIVISION


ELEVATION
56'
20
PLAN
STREET
STREET
NORTH

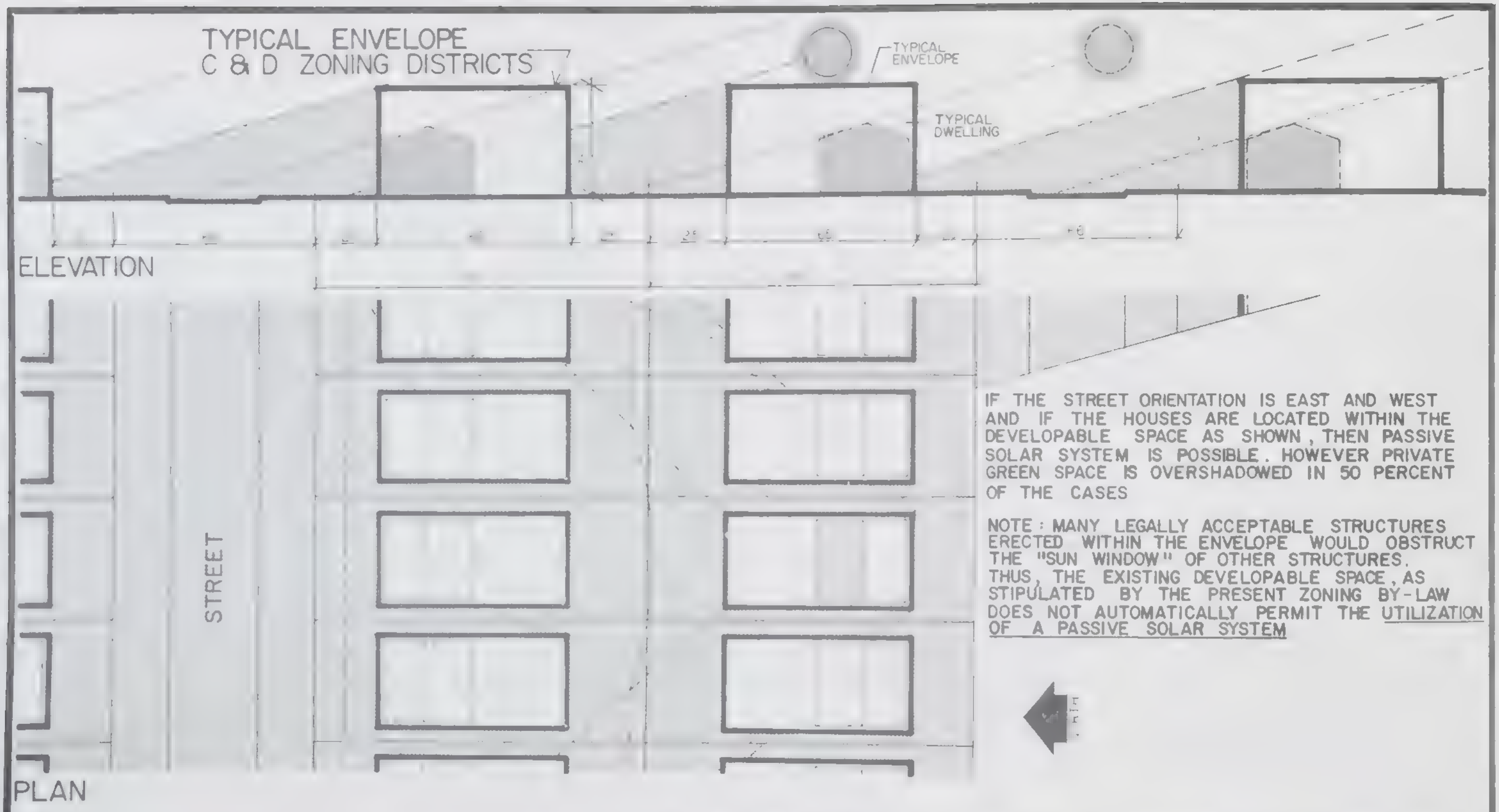
LOT SIZE
40' X 100'
SHADOW CASTING
DECEMBER 21

TYPICAL EXAMPLE OF EXISTING SUBDIVISION


ELEVATION
5
66
5
36
8
PLAN
STREET
STREET
NORTH

LOT SIZE
35' X 80'
SHADOW CASTING
DECEMBER 21

TYPICAL EXAMPLE OF EXISTING SUBDIVISION


TYPICAL ENVELOPE
C & D ZONING DISTRICTS
TYPICAL ENVELOPE
TYPICAL DWELLING
ELEVATION
STREET
PLAN

IF THE STREET ORIENTATION IS EAST AND WEST AND IF THE HOUSES ARE LOCATED WITHIN THE DEVELOPABLE SPACE AS SHOWN, THEN PASSIVE SOLAR SYSTEM IS POSSIBLE. HOWEVER PRIVATE GREEN SPACE IS OVERSHADOWED IN 50 PERCENT OF THE CASES

NOTE: MANY LEGALLY ACCEPTABLE STRUCTURES ERECTED WITHIN THE ENVELOPE WOULD OBSTRUCT THE "SUN WINDOW" OF OTHER STRUCTURES. THUS, THE EXISTING DEVELOPABLE SPACE, AS STIPULATED BY THE PRESENT ZONING BY-LAW DOES NOT AUTOMATICALLY PERMIT THE UTILIZATION OF A PASSIVE SOLAR SYSTEM

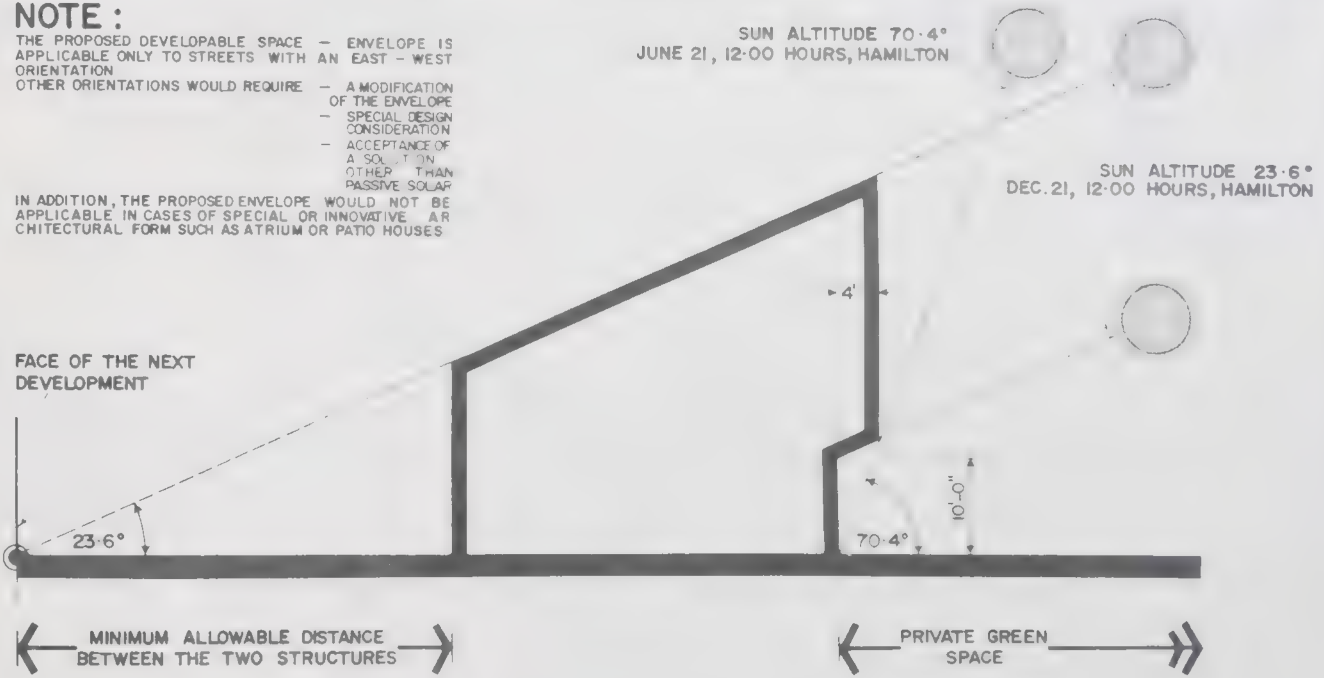
EXISTING DEVELOPABLE SPACE (ENVELOPE)

NOTE :

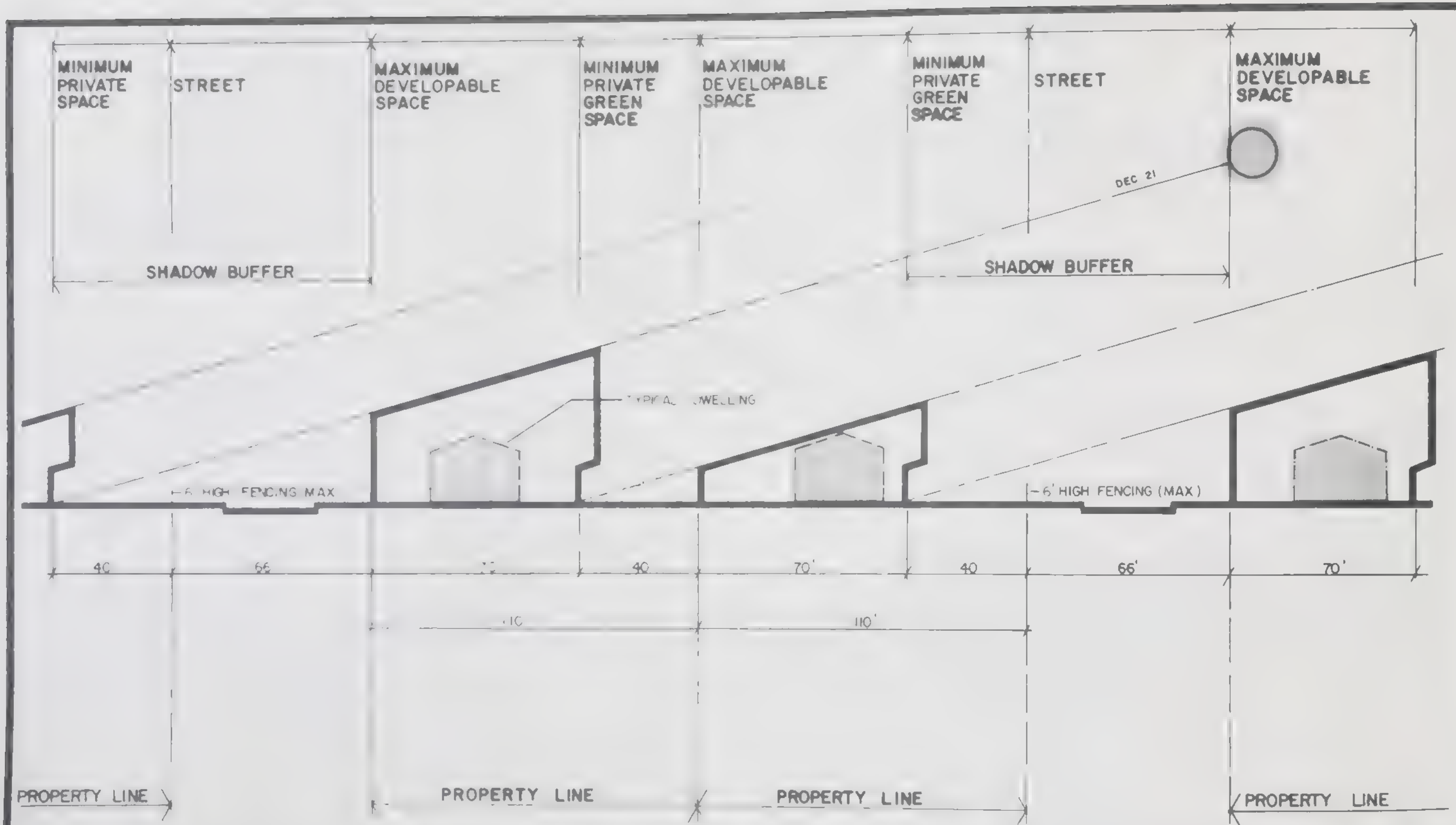
THE PROPOSED DEVELOPABLE SPACE – ENVELOPE IS APPLICABLE ONLY TO STREETS WITH AN EAST – WEST ORIENTATION

OTHER ORIENTATIONS WOULD REQUIRE
- A MODIFICATION OF THE ENVELOPE
- SPECIAL DESIGN CONSIDERATION
- ACCEPTANCE OF A SOLUTION OTHER THAN PASSIVE SOLAR

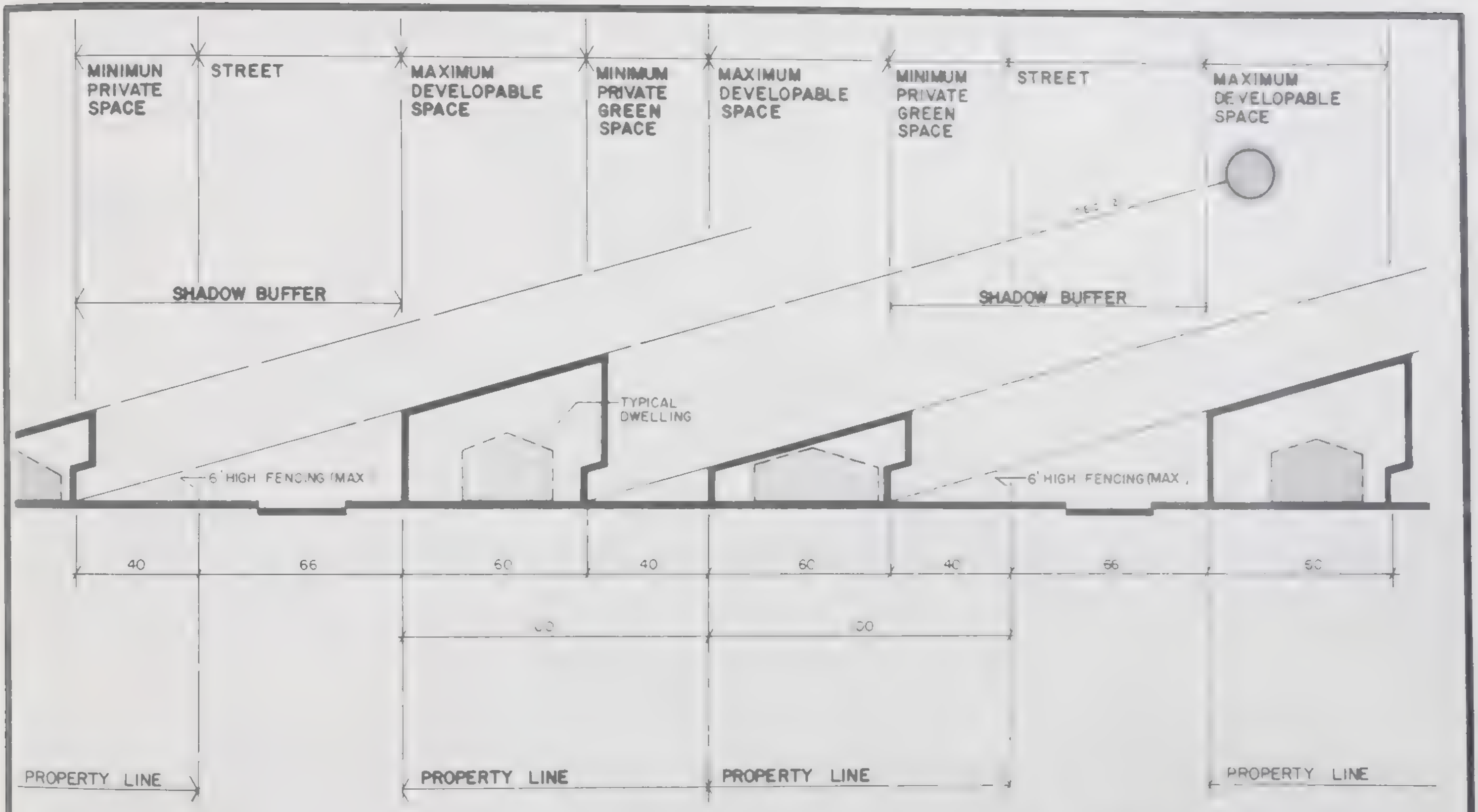
IN ADDITION, THE PROPOSED ENVELOPE WOULD NOT BE APPLICABLE IN CASES OF SPECIAL OR INNOVATIVE ARCHITECTURAL FORM SUCH AS ATRIUM OR PATIO HOUSES


SUN ALTITUDE 70·4°
JUNE 21, 12·00 HOURS, HAMILTON
SUN ALTITUDE 23·6°
DEC. 21, 12·00 HOURS, HAMILTON
FACE OF THE NEXT DEVELOPMENT
4'
10'-0"
23·6°
70·4°
MINIMUM ALLOWABLE DISTANCE BETWEEN THE TWO STRUCTURES
PRIVATE GREEN SPACE

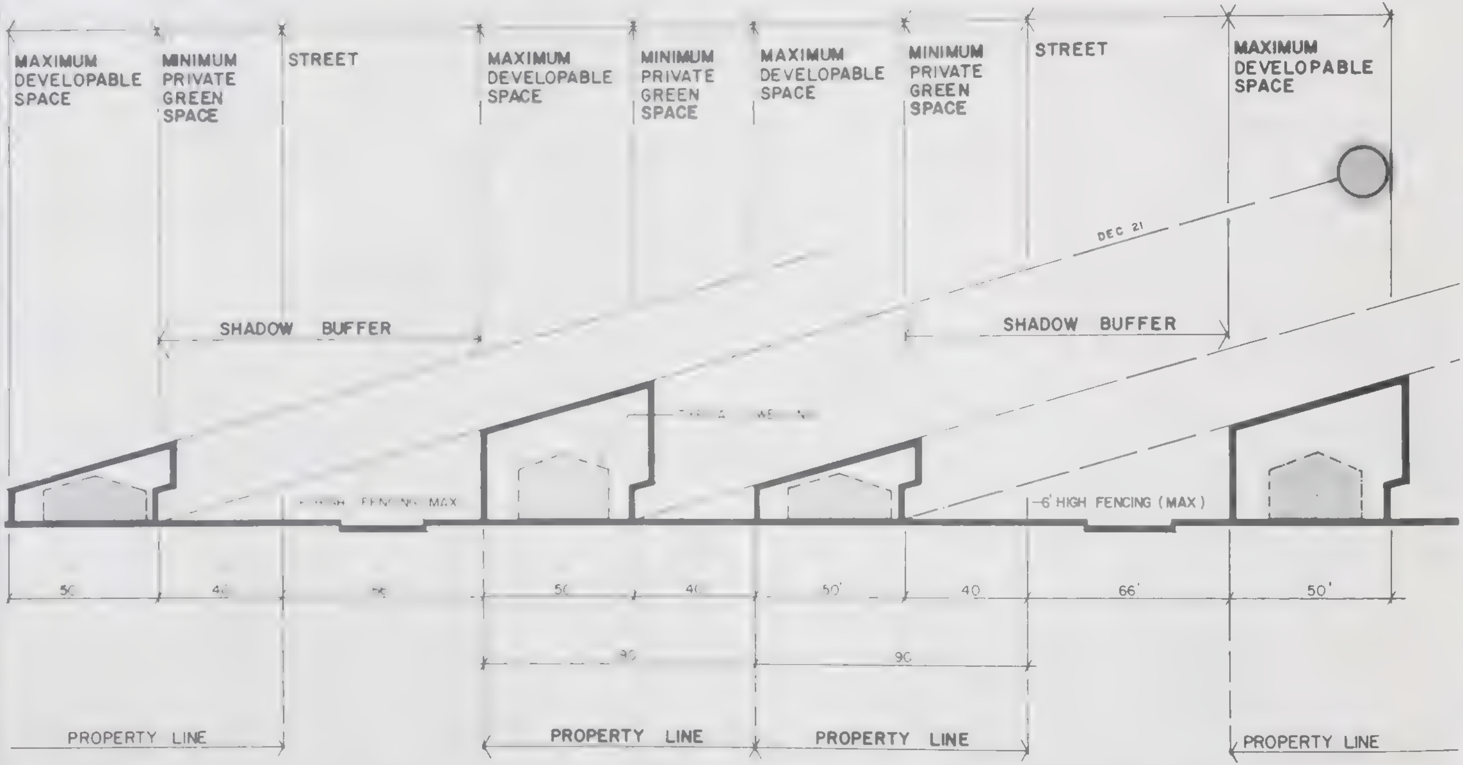
DERIVATION OF THE PROPOSED DEVELOPABLE SPACE (ENVELOPE)


MINIMUM PRIVATE SPACE
STREET
MAXIMUM DEVELOPABLE SPACE
MINIMUM PRIVATE GREEN SPACE
MAXIMUM DEVELOPABLE SPACE
MINIMUM PRIVATE GREEN SPACE
STREET
MAXIMUM DEVELOPABLE SPACE
DEC 21
SHADOW BUFFER
SHADOW BUFFER
TYPICAL DWELLING
6' HIGH FENCING MAX
6' HIGH FENCING (MAX)
40
66
70
40
70'
40
66'
70'
110
110'
PROPERTY LINE
PROPERTY LINE
PROPERTY LINE
PROPERTY LINE

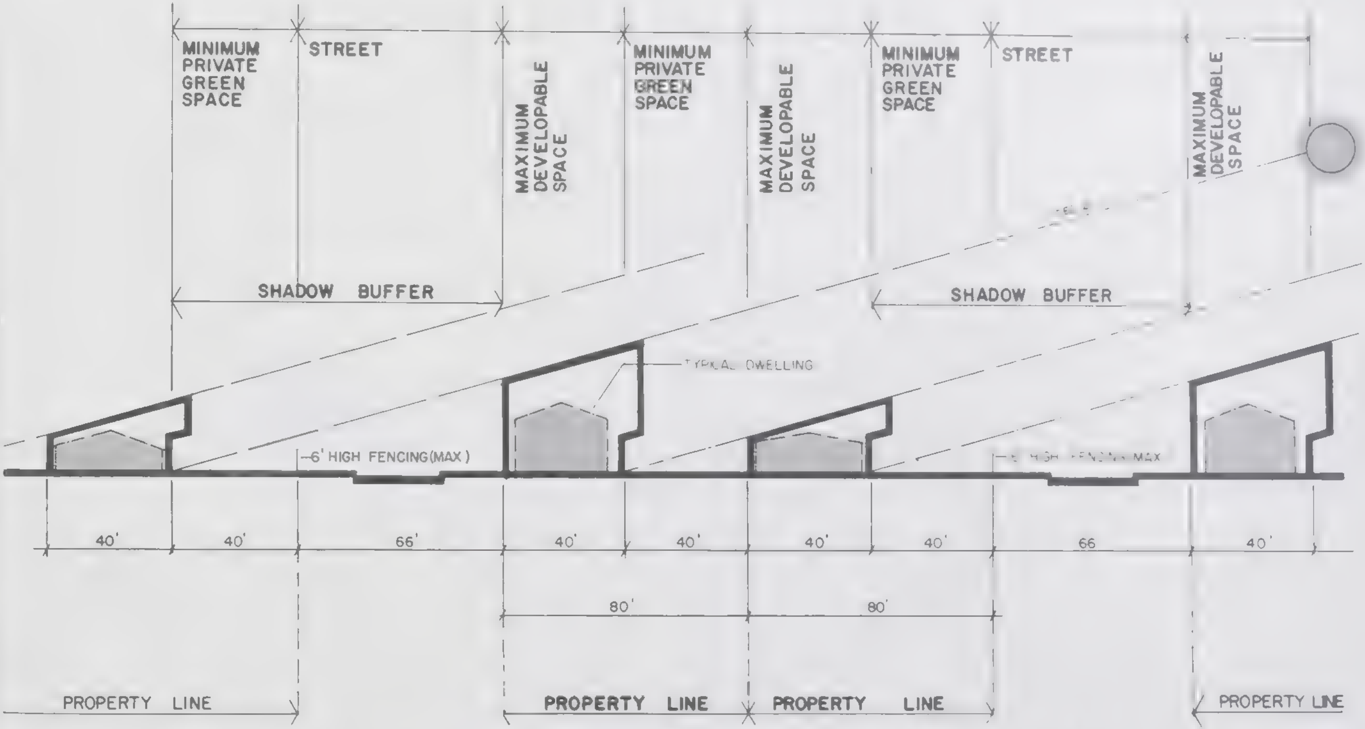
110' LOT - PROPOSED DEVELOPABLE SPACE (ENVELOPE)


MINIMUN PRIVATE SPACE
STREET
MAXIMUM DEVELOPABLE SPACE
MINIMUM PRIVATE GREEN SPACE
MAXIMUM DEVELOPABLE SPACE
MINIMUM PRIVATE GREEN SPACE
STREET
MAXIMUM DEVELOPABLE SPACE
SHADOW BUFFER
SHADOW BUFFER
TYPICAL DWELLING
6' HIGH FENCING (MAX
6' HIGH FENCING (MAX
40
66
60
40
60
40
66
60
PROPERTY LINE
PROPERTY LINE
PROPERTY LINE
PROPERTY LINE

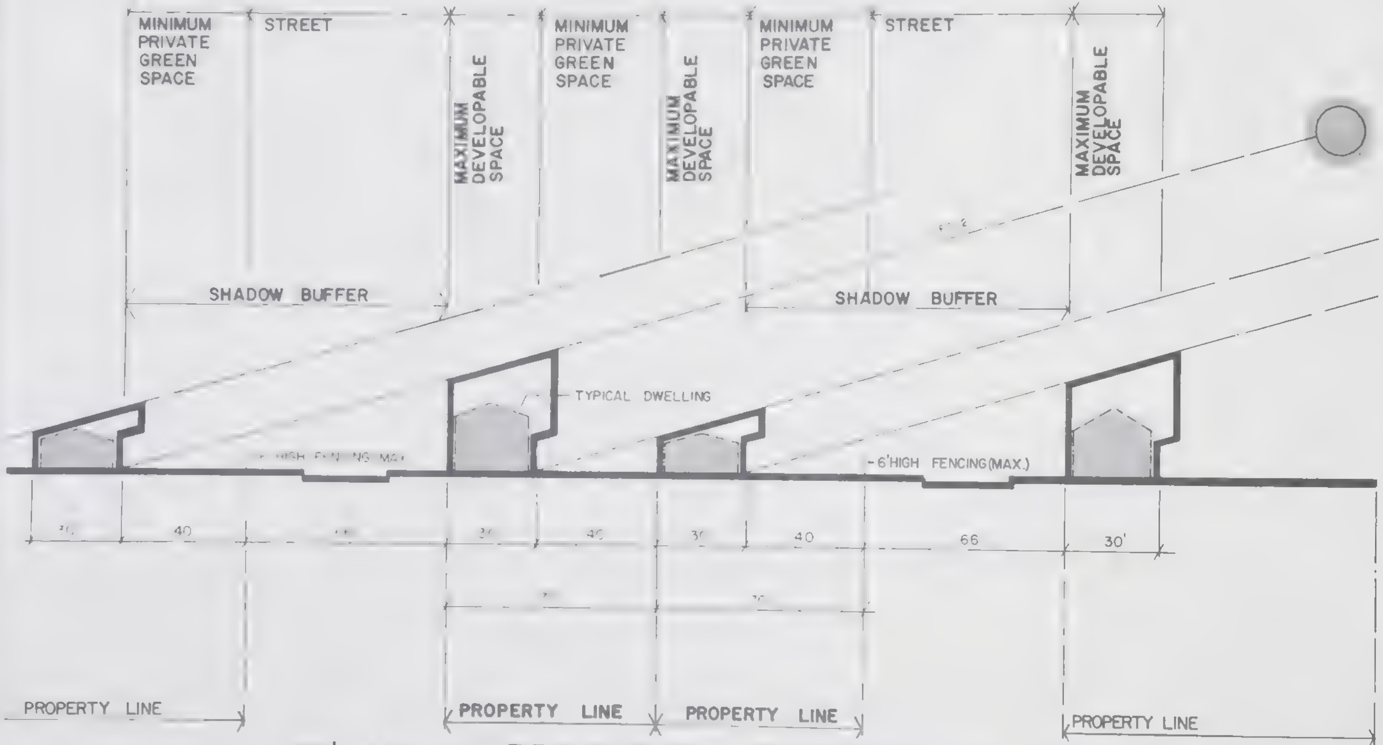
100' LOT - PROPOSED DEVELOPABLE SPACE (ENVELOPE)


MAXIMUM DEVELOPABLE SPACE
MINIMUM PRIVATE GREEN SPACE
STREET
MAXIMUM DEVELOPABLE SPACE
MINIMUM PRIVATE GREEN SPACE
MAXIMUM DEVELOPABLE SPACE
MINIMUM PRIVATE GREEN SPACE
STREET
MAXIMUM DEVELOPABLE SPACE
DEC 21
SHADOW BUFFER
SHADOW BUFFER
TYPICAL DWELLING
6' HIGH FENCING MAX
6' HIGH FENCING (MAX)
50
40
66
50
40
50'
40
66'
50'
90
90
PROPERTY LINE
PROPERTY LINE
PROPERTY LINE
PROPERTY LINE

90' LOT - PROPOSED DEVELOPABLE SPACE (ENVELOPE)


MINIMUM PRIVATE GREEN SPACE
STREET
MAXIMUM DEVELOPABLE SPACE
MINIMUM PRIVATE GREEN SPACE
MAXIMUM DEVELOPABLE SPACE
MINIMUM PRIVATE GREEN SPACE
STREET
MAXIMUM DEVELOPABLE SPACE
SHADOW BUFFER
SHADOW BUFFER
TYPICAL DWELLING
6' HIGH FENCING (MAX)
6' HIGH FENCING (MAX)
40'
40'
66'
40'
40'
40'
40'
66
40'
80'
80'
PROPERTY LINE
PROPERTY LINE
PROPERTY LINE
PROPERTY LINE

80' LOT - PROPOSED DEVELOPABLE SPACE (ENVELOPE)


MINIMUM PRIVATE GREEN SPACE
STREET
MAXIMUM DEVELOPABLE SPACE
MINIMUM PRIVATE GREEN SPACE
MAXIMUM DEVELOPABLE SPACE
MINIMUM PRIVATE GREEN SPACE
STREET
MAXIMUM DEVELOPABLE SPACE
SHADOW BUFFER
SHADOW BUFFER
TYPICAL DWELLING
6' HIGH FENCING MAX.
6'HIGH FENCING (MAX.)
30'
40
66
30
40
30
40
66
30'
70
70
PROPERTY LINE
PROPERTY LINE
PROPERTY LINE
PROPERTY LINE

70' LOT - PROPOSED DEVELOPABLE SPACE (ENVELOPE)

THE DEVELOPMENT AND REFINEMENT OF ARCHITECTURAL FORMS, AS WELL AS THE NEW GENERATION OF HIGHLY-SOPHISTICATED MECHANICAL DEVICES, SUCH AS COMPUTER-OPERATED THERMAL SYSTEMS, HEAT RECOVERY AND STORAGE SYSTEMS, HEAT PUMPS, DISTRICT HEATING, ETC., ARE COMPLIMENTARY TO THE PASSIVE APPROACH.

SOME OF THESE IDEAS ARE DISCUSSED ON THE FOLLOWING PAGES.

OTHER CONSIDERATIONS

WITH MORE PRESSURE FOR AN EFFICIENT UTILIZATION OF LAND, THE NEED FOR HOUSE DESIGN INNOVATION WILL GROW. HOWEVER, NEW FORMS OF ARCHITECTURAL DESIGN DO NOT NECESSARILY REQUIRE A GENUINE INVENTION. WE CAN BORROW OR ADAPT OLD CONCEPTS WHICH SUIT OUR PRESENT NEEDS AND REQUIREMENTS. ONE VERY OLD AND VERY ATTRACTIVE DESIGN CONCEPT WHICH WOULD FIT OUR ENERGY EFFICIENT "HIGH DENSITY/LOW RISE" REQUIREMENTS IS THE ATRIUM HOUSE (ALSO CALLED THE "SPANISH COURT HOUSE" OR "ROMAN COURT HOUSE"). THIS TYPE OF HOUSE CAN BE LOCATED ON AN INDIVIDUAL LOT WITH ALL SETBACKS AS REQUIRED BY CURRENT PRACTICE. BUT, BY VIRTUE OF ITS LAYOUT, THE MINIMUM SIZE OF THE LOT REQUIRED COULD BE AS SMALL AS THE SIZE OF THE HOUSE. A TRUE FOUR-SIDED ZERO LOT LINE IDEA.

SOME DEVELOPMENTS WHICH FULLY UTILIZE THE ATRIUM DESIGN CONCEPT ARE ACHIEVING DENSITIES OF UP TO 200 PERSONS PER ACRE. INTERESTINGLY, NONE OF THE STRUCTURES ARE MORE THAN TWO STORIES HIGH, YET THEY OFFER THE UTMOST IN PRIVACY AND PROVIDE A FAMILY LIVING ENVIRONMENT SUPERIOR TO THAT IN ANY CONVENTIONAL SUBDIVISION DEVELOPMENT.

THE COMBINATION OF AN ATRIUM HOUSE WITH A [illegible] CONCEPT IS CALLED THE [illegible]. IT OFFERS FURTHER ADVANTAGES. IN ADDITION TO THE INTEGRATED GARDEN, THIS [illegible] CONCEPT ALSO UTILIZES THE LOWER PART OF THE BUILDING [illegible] [illegible]. THE [illegible] CONCEPT ALSO OFFERS THE UTILIZATION OF ATTACHABLE GREENHOUSES AND WINTER GARDENS AND MAKES IT POSSIBLE TO DESIGN A RELATIVELY SIMPLE PERMANENT OR [illegible] THE ATRIUM. THE PRIVATE OPEN SPACE OF "GREEN ROOM" IS SUITABLE FOR ALMOST ANY FORM OF FAMILY RECREATION VIRTUALLY THROUGHOUT THE YEAR.

THE ATRIUM AND THE PATIO GARDEN COMPRISES INNER PRIVACY AND SERVE THE FAMILY AS THE PSYCHOLOGICAL CENTRE OF THE HOME. THUS, THIS DESIGN CONCEPT PROVIDES A SUPERIOR FAMILY ENVIRONMENT AND LIVING QUALITY UNMATCHED BY ANY PRESENTLY-BUILT HOUSE FORM.

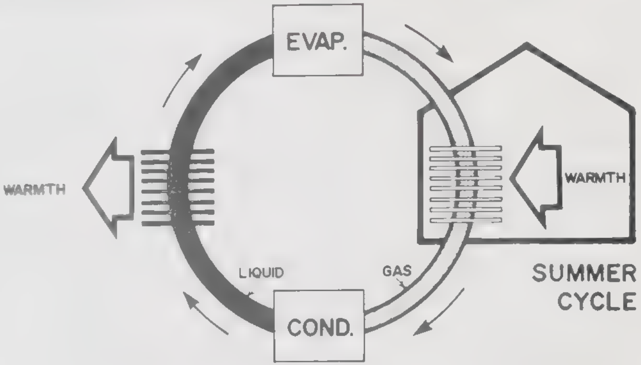
ATRIUM AND PATIO HOUSES ARE VERY ENERGY EFFICIENT.

A HEAT PUMP IS A DEVICE WHICH TRANSFERS THERMAL ENERGY OR HEAT FROM A COOLER REGION TO A WARMER ONE THE DIRECTION OF ENERGY TRANSFER IS CONTRARY TO THE NORMAL FLOW HEAT NATURALLY FLOWS FROM A WARMER REGION TO A COOLER REGION

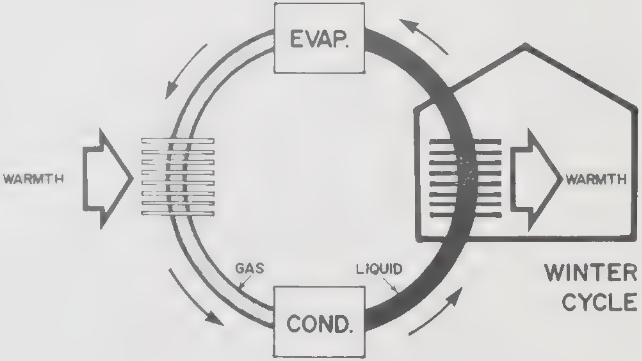
A REFRIGERATOR ACTS AS A HEAT PUMP THE RADIATOR AT THE BACK OF THE REFRIGERATOR IS WARM THIS IS THE HEAT EXTRACTED FROM THE INTERIOR OF THE FRIDGE A HEAT PUMP IS SIMPLY A REFRIGERATOR WHICH CAN OPERATE IN "TWO DIRECTIONS, ENABLING THE SAME EQUIPMENT TO HEAT OR COOL A GIVEN SPACE."

DURING THE HEATING MODE, LOW TEMPERATURE (LIQUID) FREON IS PUMPED THROUGH THE EVAPORATOR WHERE IT ABSORBS HEAT FROM THE SOURCE, (AIR, WATER, EARTH), AND GASIFIES IT IS THEN COMPRESSED TO A MODERATELY HIGH TEMPERATURE AND PRESSURE, AND FORCED THROUGH THE CONDENSOR WHERE IT IT RELEASES ITS HEAT TO THE ROOM AS IT RETURNS TO A LIQUID STATE TO BEGIN THE CYCLE AGAIN A FAN BLOWING AIR OVER THE CONDENSOR CIRCULATES WARM AIR THROUGH THE ROOM DURING THE COOLING MODE, THIS PROCESS IS REVERSED THE ROOM BECOMES THE SOURCE FROM WHICH HEAT IS EXTRACTED AND THE OUTSIDE BECOMES THE SINK AREA THE EVAPORATOR, OF COURSE, IS COLD AND THEREFORE THE FAN CIRCULATES COOL AIR

AT PRESENT, HEAT PUMPS ARE NOT VERY EFFICIENT AT LOW OUTSIDE TEMPERATURES. SOME SYSTEMS EXTRACT HEAT FROM UNDERGROUND WATER OR SOIL. HEAT PUMPS CAN ALSO BE COMBINED WITH SOLAR COLLECTORS GENERALLY HEAT PUMPS ARE VERY PROMISING RESIDENTIAL HEAT SYSTEMS



SUMMER CYCLE



WINTER CYCLE

HEAT PUMP – COOLING & HEATING CYCLE

THE TIME WHEN EVERY ROOM IN THE HOUSE WAS HEATED BY ITS OWN STOVE IS STILL IN LIVING MEMORY. THE SAME HELD TRUE FOR EVERY ROOM OF A FLAT IN AN APARTMENT BUILDING AND EVERY OFFICE IN AN OFFICE BUILDING. IT WAS A GREAT LEAP FORWARD TOWARD EFFICIENCY TO PROVIDE HOUSES WITH CENTRAL HEATING SYSTEMS. THE FURNACE WENT INTO THE BASEMENT. IN LARGER BUILDINGS, IT WAS RELOCATED TO THE MECHANICAL ROOM. THE NEXT AND OBVIOUS STEP WAS TO BUILD A "SUPER FURNACE" FOR A GROUP OF HOUSES OR FOR A GROUP OF BUILDINGS. THE INNOVATION WAS NAMED "DISTRICT HEATING". A DISTRICT HEATING SYSTEM CAN BE FED BY ANY KNOWN FUEL. THIS INCLUDES [illegible] AND NUCLEAR SYSTEMS. ALSO, IT CAN FUNCTION AS A DISTRICT HEAT EXCHANGER TO UTILIZE EXCESS HEAT FROM INDUSTRIAL AND COMMERCIAL ESTABLISHMENTS WHICH OTHERWISE WOULD BE DUMPED.

THE DISTRICT HEATING SYSTEM WAS VERY POPULAR BEFORE THE SECOND WORLD WAR. LATER, IN THE AGE OF (PRACTICALLY) FREE ENERGY, A CALL FOR EFFICIENCY WAS CONSIDERED TO BE MEANINGLESS OR EVEN ECCENTRIC. THE FURTHER DEVELOPMENT AND USE OF DISTRICT HEATING SYSTEMS CAME TO A HALT.

DISTRICT HEATING

AT PRESENT, WE ARE EXPERIENCING A RENEWED INTEREST IN DISTRICT HEATING. IT HAS TO BE UNDERSTOOD THAT THE ECONOMY AND EFFICIENCY OF THIS SYSTEM IS RELATED TO THE DISTANCE OVER WHICH THE HEAT HAS TO BE CARRIED. THE FURNACE IN OUR BASEMENT WOULD GO MAD IF EVERY ROOM OF OUR HOUSE WERE TO BE BUILT AS A SEPARATE STRUCTURE, YARDS AND YARDS AWAY. THE CHALLENGE OF DESIGNING RESIDENTIAL DEVELOPMENTS HEATED BY DISTRICT HEATING SYSTEMS LIES IN PHYSICAL PROXIMITIES AND COMPACTNESS. ALTHOUGH WE HAVE TO DEAL WITH HIGHER DENSITIES, QUALITY AND SPATIAL COMFORT MUST NOT BE SACRIFICED. AN INNOVATIVE ARCHITECTURAL FORM CAN DO THE TRICK.

A shadow template set is the simplest tool for determining the size and direction of shadows cast by any natural or man-made object.

With no section drawing required, the set can be used for:

1. The design and evaluation of development proposals, plans, landscape and architectural designs, and even interior layouts. Shadow templates make possible a quick determination of shadows at 0900, 1000, 1200, 1400 and 1500 hours on the 21st day of every month.
   Formula: Shadow Length = Height x Coefficient
2. A determination of the height of the object, if the length of the shadow is stipulated. Thus, we can arrive at the permissible height of adjacent structures, trees, the height and size of an overhang, sunscreen, and also arrive at the desirable size and shape of windows, skylights and other openings and architectural features.
   Formula: Height = Shadow Length ÷ Coefficient

SHADOW TEMPLATES

USE OF SHADOW TEMPLATE

TASK I

FIND THE SHADOW OF A 10 FOOT HIGH POLE AT 09 00, 10.00, 12 00; 14.00; AND 15 00 HOURS
DATE DECEMBER 21 ST
LATITUDE 43 DEGREES NORTH (HAMILTON)
SLOPE 0% (FLAT LAND)

STEP 1

SELECT THE CORRESPONDING TEMPLATE (I.E DECEMBER 21)

STEP 2

SEE FIGURE 2

STEP 3

SEE FIGURE 3

STEP 4

MULTIPLY THE HEIGHT OF THE OBJECT BY BY THE APPROPRIATE FIGURES ON THE TEMPLATE PROVIDED FOR EACH TIME PERIOD; FOR EXAMPLE
AT 09 00 HOURS SHADOW OF OBJECT EQUALS HEIGHT OF OBJECT TIMES CONSTANT,
(10'x 4 828' = 48 28 FEET)
THEREFORE, 48.28 IS THE LENGTH OF THE SHADOW CREATED BY THE OBJECT AT THAT PARTICULAR TIME (09 00 HOURS);
-REPEAT THIS PROCESS FOR ALL OTHER TIMES

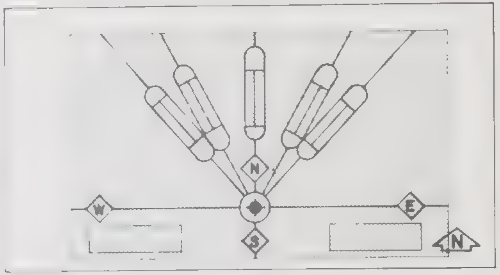
STEP 5

REMOVE THE TEMPLATE

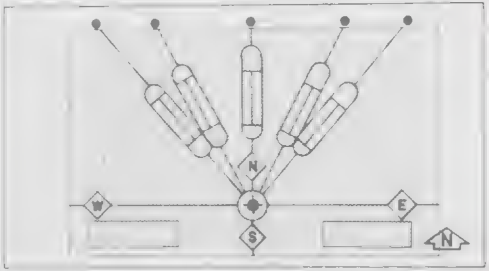
STEP 6

SEE FIGURE 4

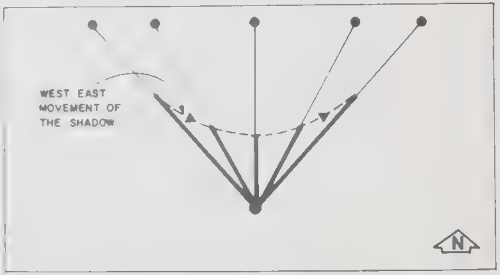
1. PLAN OF 10 FOOT POLE.



2. OVERLAY THE CENTRE OF THE CROSS IN THE CIRCLE ON THE CORRESPONDING TEMPLATE ONTO THE CENTRE OF THE OBJECT (I.E. 10 FOOT POLE). MAKE SURE THE POSITION OF THE NORTH POINT OF THE PLAN COINCIDES WITH THE NORTH POINT OF THE TEMPLATE.

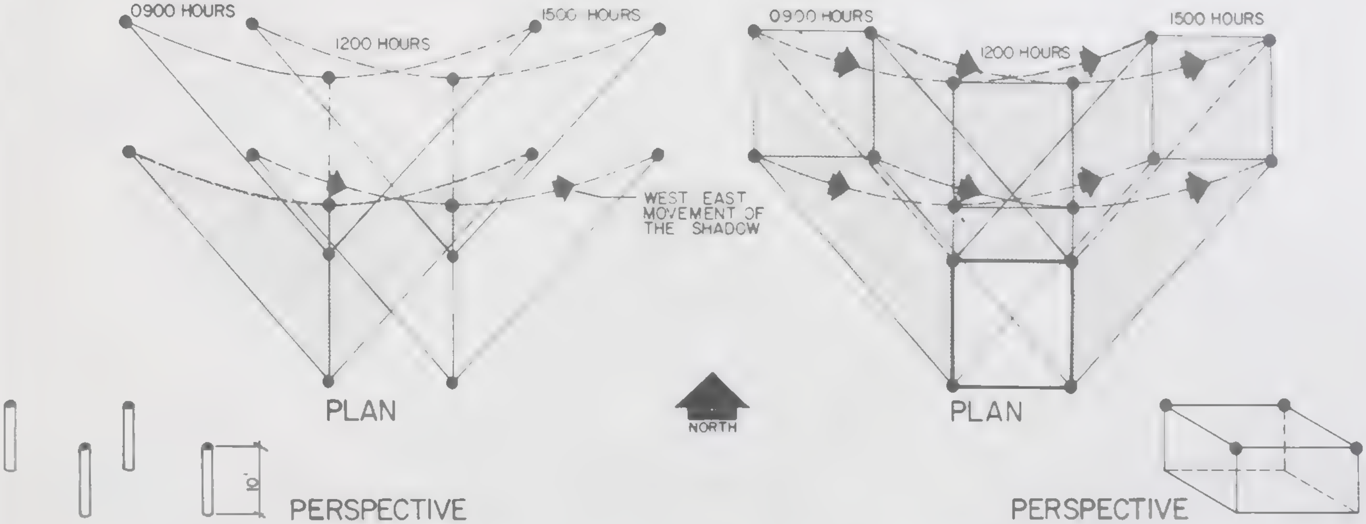


3. TO TRANSFER ALL FIVE LINES INDICATED ON THE TEMPLATE (UPPER EDGE OF ACETATE) ONTO THE PLAN THAT THE OBJECT (I.E 10 FOOT POLE) IS DRAWN ON, MAKE A MARK BETWEEN THE EDGE OF TEMPLATE AT THE APPROPRIATE LINE AND THE PLAN OBJECT IS DRAWN ON.



4. JOIN ALL FIVE MARKS ON THE PLAN TO THE CENTRE OF THE OBJECT AND MARK CALCULATED SHADOW LENGTHS ON THE RESPECTIVE LINES I.E. 09·00 HOURS · · 48·28 FEET, 10·00 HOURS · · 30·77 FEET, 12·00 HOURS · · 22·88 FEET, 14·00 HOURS · · 30·77 FEET, AND 15·00 HOURS · · 48·28 FEET.

SHADOW PATTERN


0900 HOURS
1200 HOURS
1500 HOURS
WEST EAST MOVEMENT OF THE SHADOW
PLAN
10'
PERSPECTIVE
NORTH
0900 HOURS
1200 HOURS
1500 HOURS
PLAN
PERSPECTIVE

TASK : 2 (DECEMBER 21)

DRAW SHADOWS OF FOUR POLES EACH 10 FEET HIGH

STEP 1 SIMILARLY PLACE THE SHADOW TEMPLATE ON EACH POLE AND MARK THREE POINTS 0900 , 1200 AND 1500 HOURS FOR EACH POLE

STEP 2 CONNECT CASTED SHADOWS AS SHOWN

TASK : 3 (DECEMBER 21)

DRAW A COMPOSITE SHADOW OF A CUBICLE SHOWN ON THE PLAN . THE HEIGHT IS 10 FEET.

STEP 1 THE SAME AS TASK 2

STEP 2 CONNECT CASTED SHADOWS AS SHOWN

SHADOW PATTERN

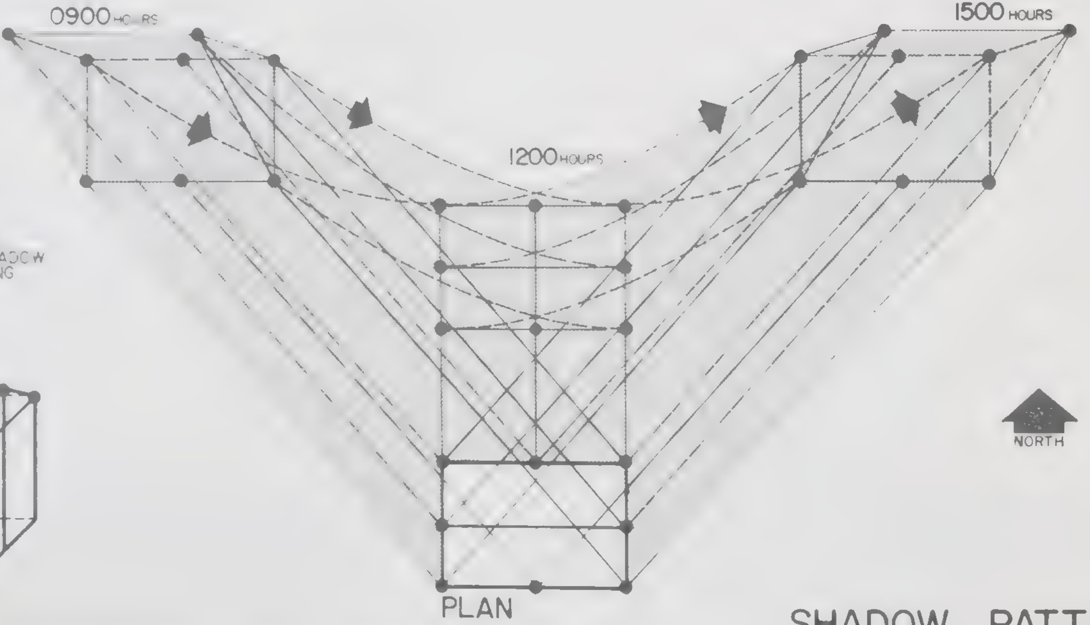
TASK : 4

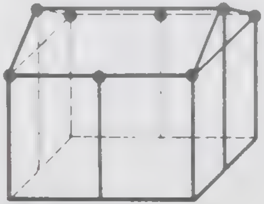
DRAW A COMPOSITE SHADOW (0900 – 1500) OF THE GIVEN BUILDING (DECEMBER 21)

STEP : 1
ABSTRACT THE BUILDING INTO A NUMBER OF POLES

STEP : 2
DEVELOP SHADOW LENGTHS FOR EACH POLE ON THE PLAN

STEP 3
CONNECT THE SHADOW LENGTH LINES FROM THE POLES TO ARRIVE AT THE SHADOW PATTERN OF THE BUILDING


0900 HOURS
1500 HOURS
1200 HOURS
NORTH
PLAN



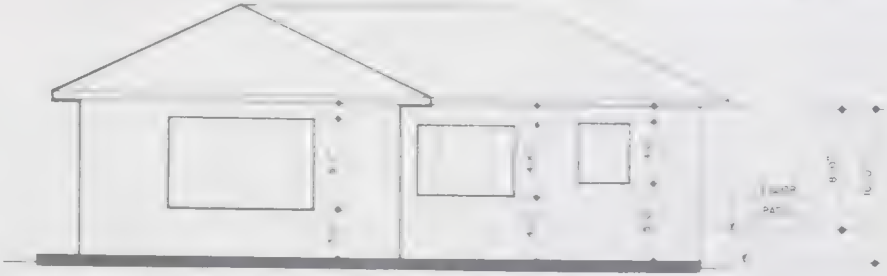
PERSPECTIVE

SHADOW PATTERN

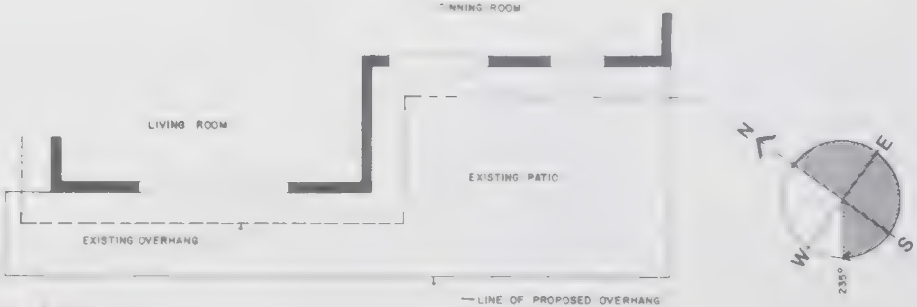
TASK : 5

DESIGN AN OVERHEAD SUNSCREEN FOR AN EXISTING OUTDOOR PATIO. SUN LIGHT MUST BE ALLOWED TO ENTER THE DWELLING DURING THE PERIOD BETWEEN SEPTEMBER AND MARCH.

THE FACE OF THE HOUSE IS 235° DUE NORTH.



ELEVATION

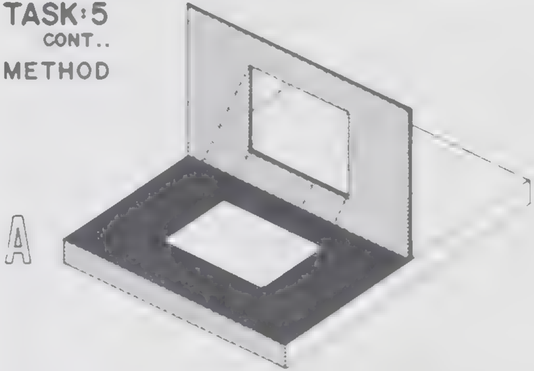


NNING ROOM
LIVING ROOM
EXISTING PATIO
EXISTING OVERHANG
LINE OF PROPOSED OVERHANG
N
E
S
W.
235°

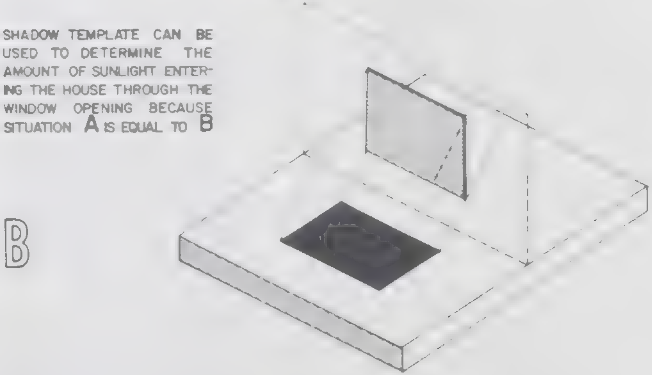
PLAN

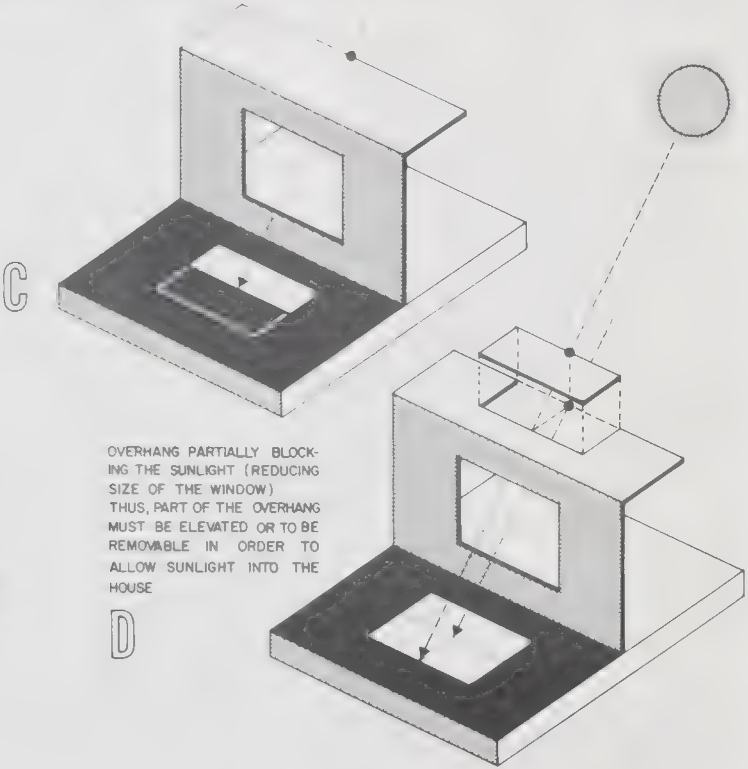
SHADOW PATTERN

TASK:5
CONT..
METHOD



SHADOW TEMPLATE CAN BE USED TO DETERMINE THE AMOUNT OF SUNLIGHT ENTERING THE HOUSE THROUGH THE WINDOW OPENING BECAUSE SITUATION A IS EQUAL TO B

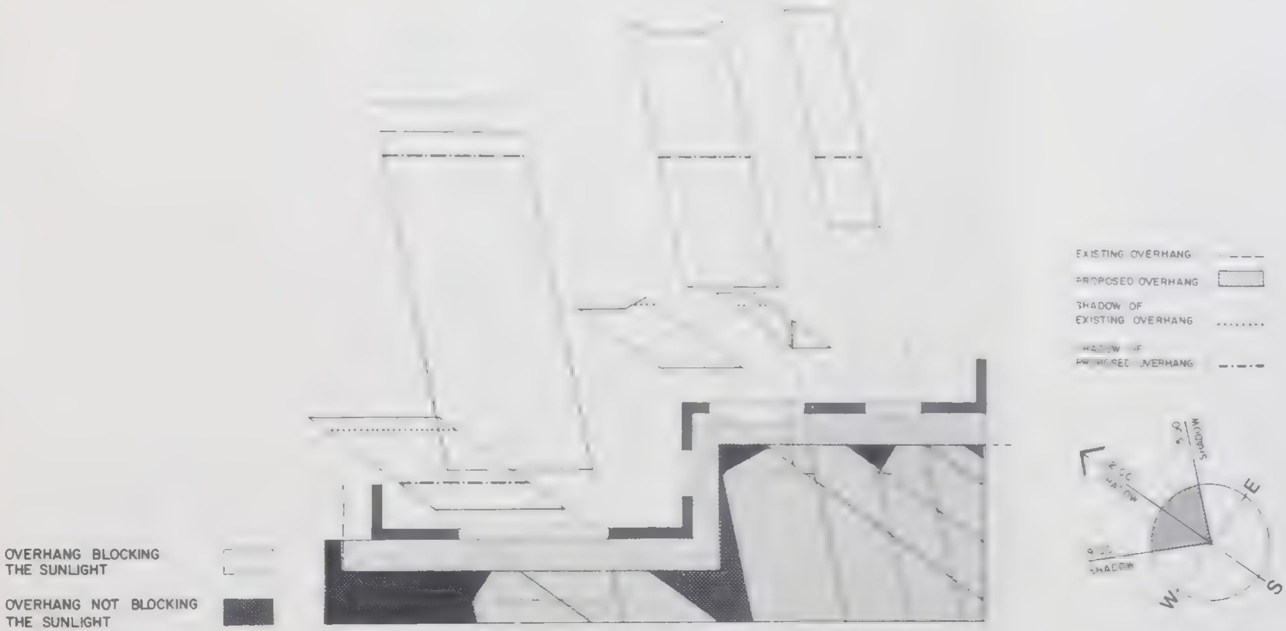




OVERHANG PARTIALLY BLOCKING THE SUNLIGHT (REDUCING SIZE OF THE WINDOW) THUS, PART OF THE OVERHANG MUST BE ELEVATED OR TO BE REMOVABLE IN ORDER TO ALLOW SUNLIGHT INTO THE HOUSE

SHADOW PATTERN

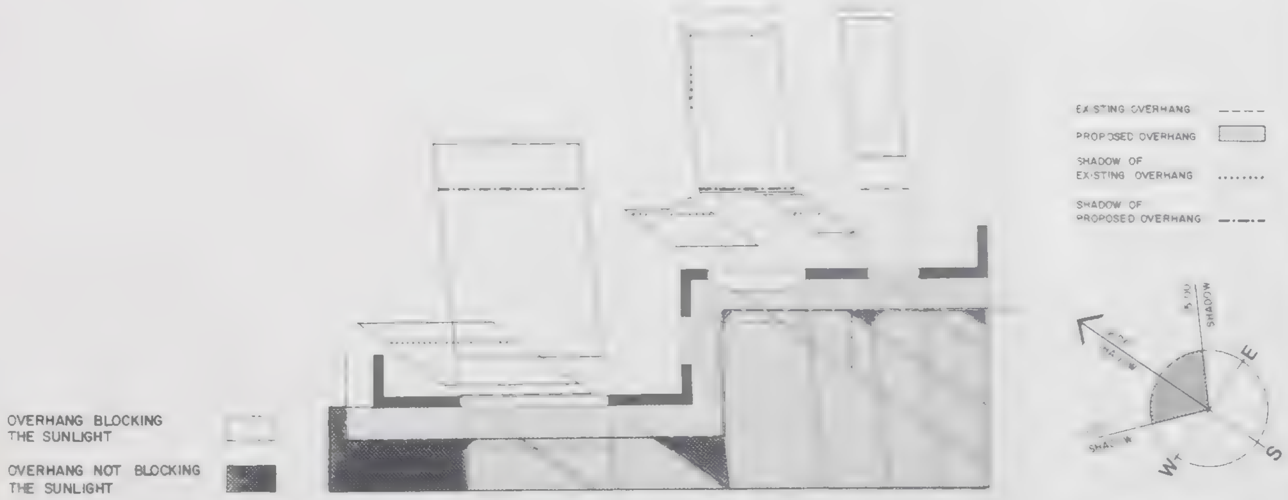
TASK : 5 CONT..


EXISTING OVERHANG
PROPOSED OVERHANG
SHADOW OF EXISTING OVERHANG
SHADOW OF PROPOSED OVERHANG
12:00 SHADOW
3:00 SHADOW
9:00 SHADOW
E
S
W
OVERHANG BLOCKING THE SUNLIGHT
OVERHANG NOT BLOCKING THE SUNLIGHT

JANUARY 21

SHADOW PATTERN

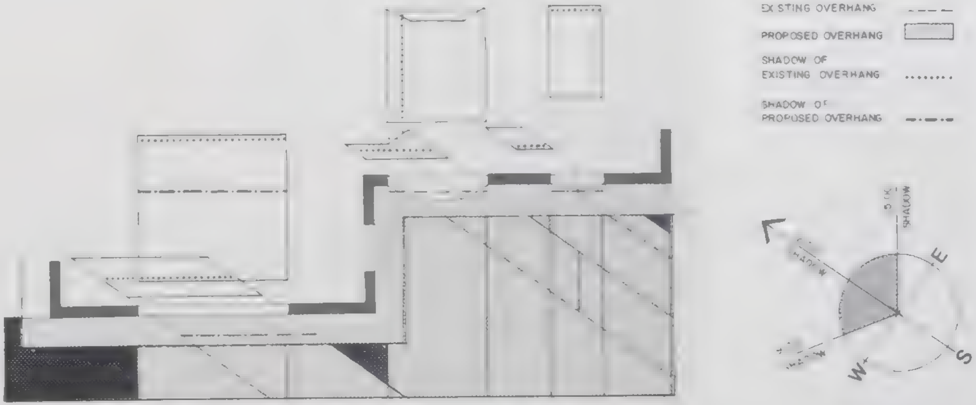
TASK : 5 CONT..


EXISTING OVERHANG
PROPOSED OVERHANG
SHADOW OF EXISTING OVERHANG
SHADOW OF PROPOSED OVERHANG
OVERHANG BLOCKING THE SUNLIGHT
OVERHANG NOT BLOCKING THE SUNLIGHT
SHADOW
E
S
W

FEBRUARY 21

SHADOW PATTERN

TASK : 5 CONT..


EXISTING OVERHANG
PROPOSED OVERHANG
SHADOW OF EXISTING OVERHANG
SHADOW OF PROPOSED OVERHANG
SHADOW
SHADOW
E
S
W

OVERHANG BLOCKING THE SUNLIGHT ☐

OVERHANG NOT BLOCKING THE SUNLIGHT ■

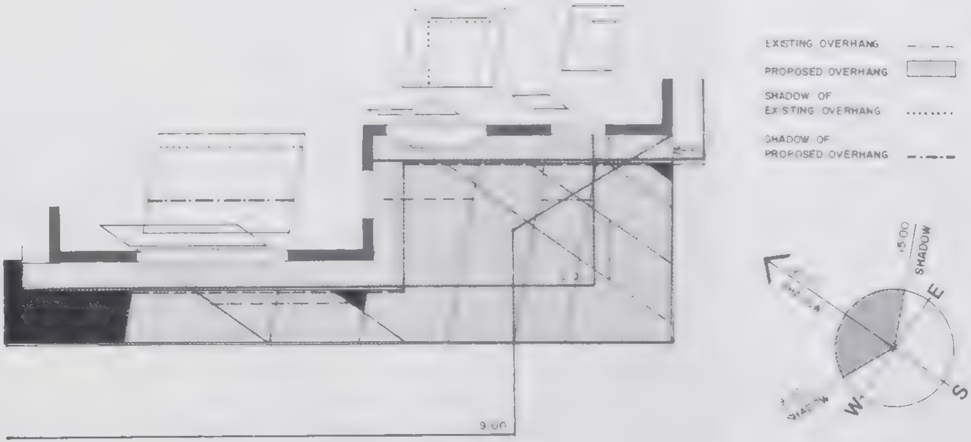
MARCH 21

SHADOW PATTERN

TASK : 5 CONT..

OVERHANG BLOCKING THE SUNLIGHT ☐

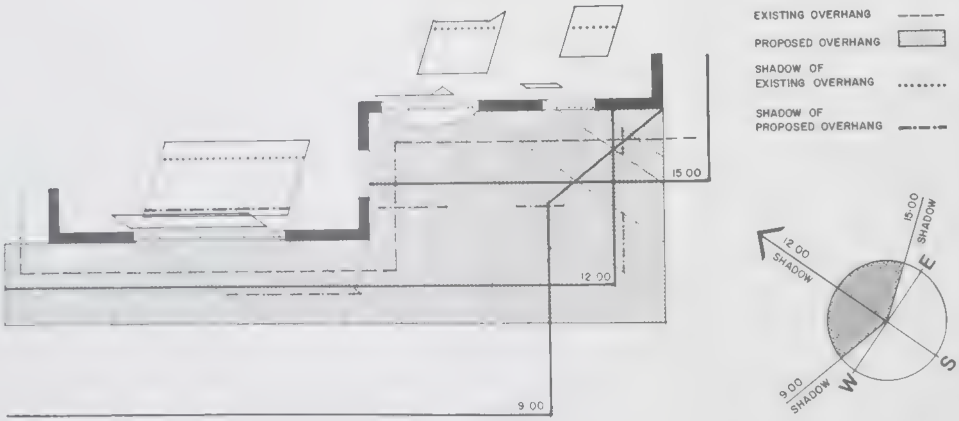
OVERHANG NOT BLOCKING THE SUNLIGHT ■


9.00
EXISTING OVERHANG
PROPOSED OVERHANG
SHADOW OF EXISTING OVERHANG
SHADOW OF PROPOSED OVERHANG
15.00
SHADOW
E
S
W
SHADOW

APRIL 21

SHADOW PATTERN

TASK : 5 CONT..

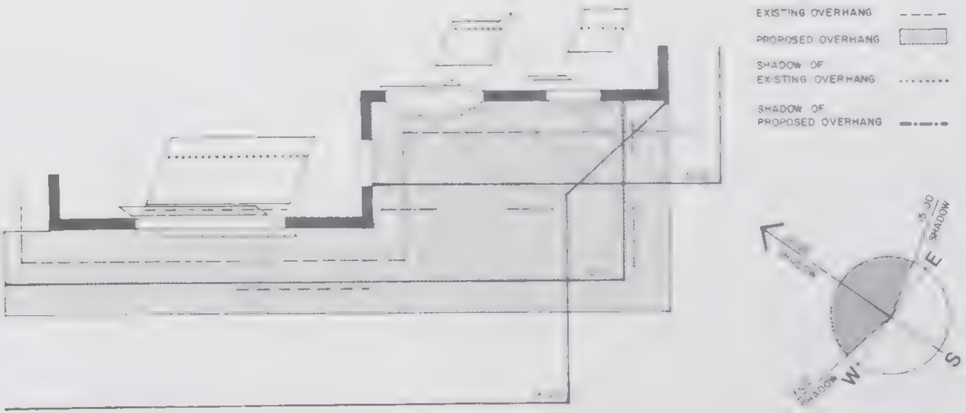


EXISTING OVERHANG
PROPOSED OVERHANG
SHADOW OF EXISTING OVERHANG
SHADOW OF PROPOSED OVERHANG
15 00
12 00
9 00
12 00 SHADOW
15:00 SHADOW
9.00 SHADOW
E
S
W

MAY 21

SHADOW PATTERN

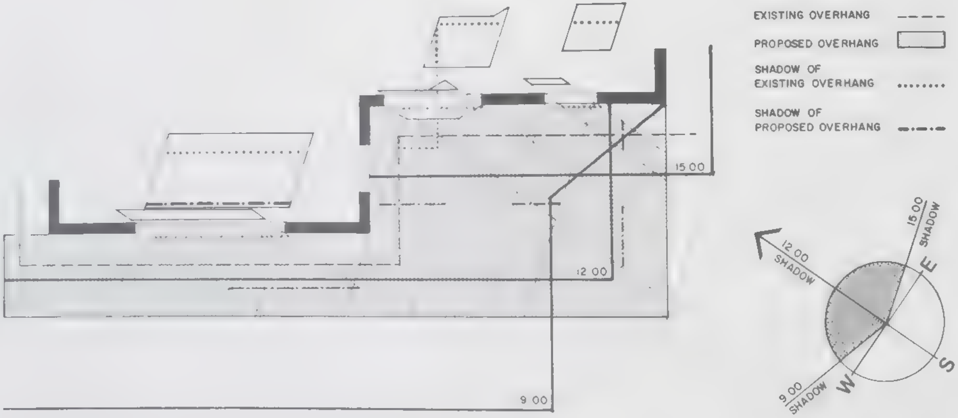
TASK : 5 CONT..


EXISTING OVERHANG
PROPOSED OVERHANG
SHADOW OF EXISTING OVERHANG
SHADOW OF PROPOSED OVERHANG
SHADOW
E
S
W
SHADOW

JUNE 21

SHADOW PATTERN

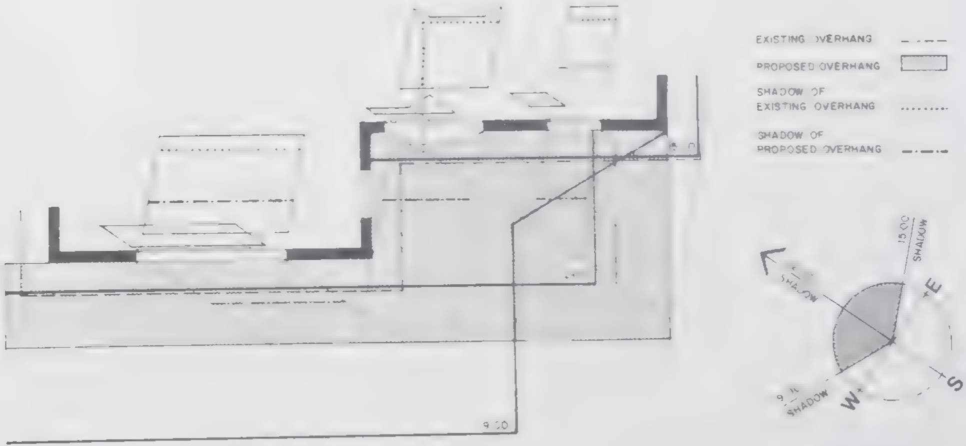
TASK : 5 CONT..


EXISTING OVERHANG
PROPOSED OVERHANG
SHADOW OF EXISTING OVERHANG
SHADOW OF PROPOSED OVERHANG
15 00
12 00
9 00
12 00 SHADOW
15 00 SHADOW
9 00 SHADOW
E
W
S

JULY 21

SHADOW PATTERN

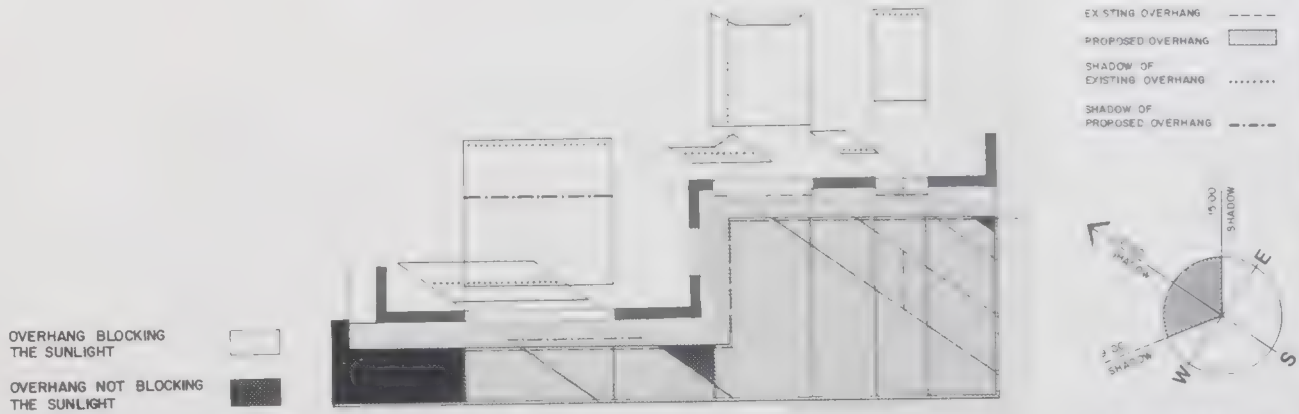
TASK: 5 CONT..


EXISTING OVERHANG
PROPOSED OVERHANG
SHADOW OF EXISTING OVERHANG
SHADOW OF PROPOSED OVERHANG
9:20
15:00
SHADOW
SHADOW
SHADOW
E
S
W

AUGUST 21

SHADOW PATTERN

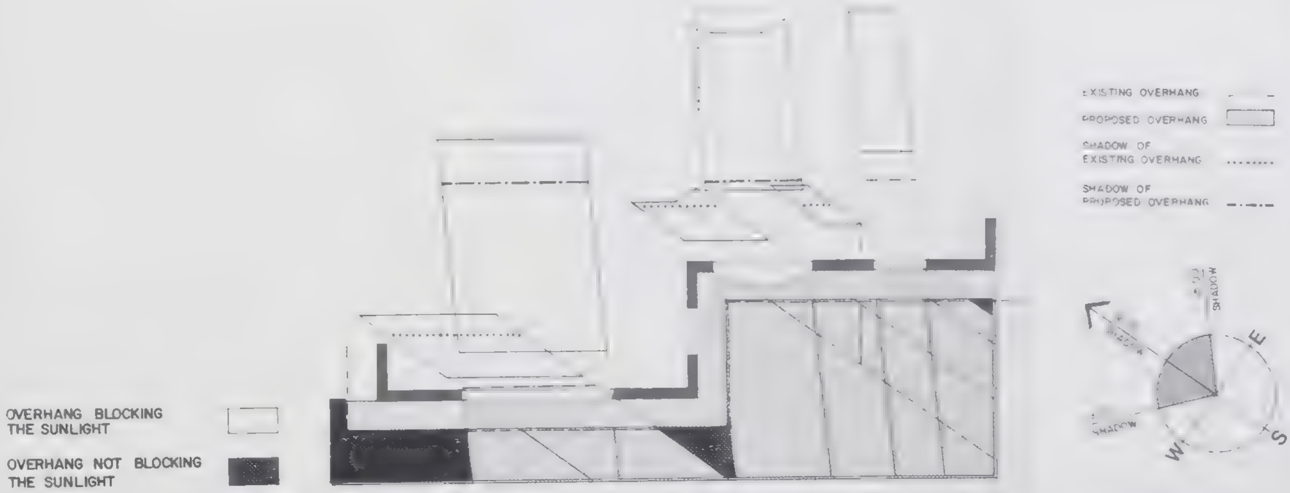
TASK : 5 CONT..


EXISTING OVERHANG
PROPOSED OVERHANG
SHADOW OF EXISTING OVERHANG
SHADOW OF PROPOSED OVERHANG
15:00 SHADOW
SHADOW
SHADOW
E
S
W
OVERHANG BLOCKING THE SUNLIGHT
OVERHANG NOT BLOCKING THE SUNLIGHT

SEPTEMBER 21

SHADOW PATTERN

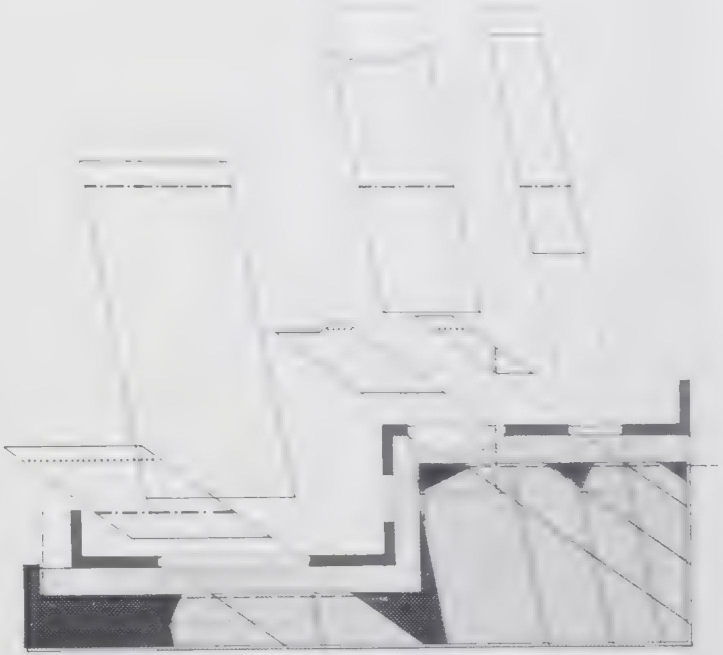
TASK : 5 CONT..


EXISTING OVERHANG
PROPOSED OVERHANG
SHADOW OF EXISTING OVERHANG
SHADOW OF PROPOSED OVERHANG
SHADOW
SHADOW
E
S
W
OVERHANG BLOCKING THE SUNLIGHT
OVERHANG NOT BLOCKING THE SUNLIGHT

OCTOBER 21

SHADOW PATTERN

TASK : 5 CONT..



EXISTING OVERHANG - - - -

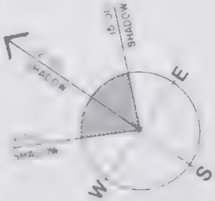
PROPOSED OVERHANG ▭

SHADOW OF EXISTING OVERHANG ....

SHADOW OF PROPOSED OVERHANG —·—·—

OVERHANG BLOCKING THE SUNLIGHT ☐

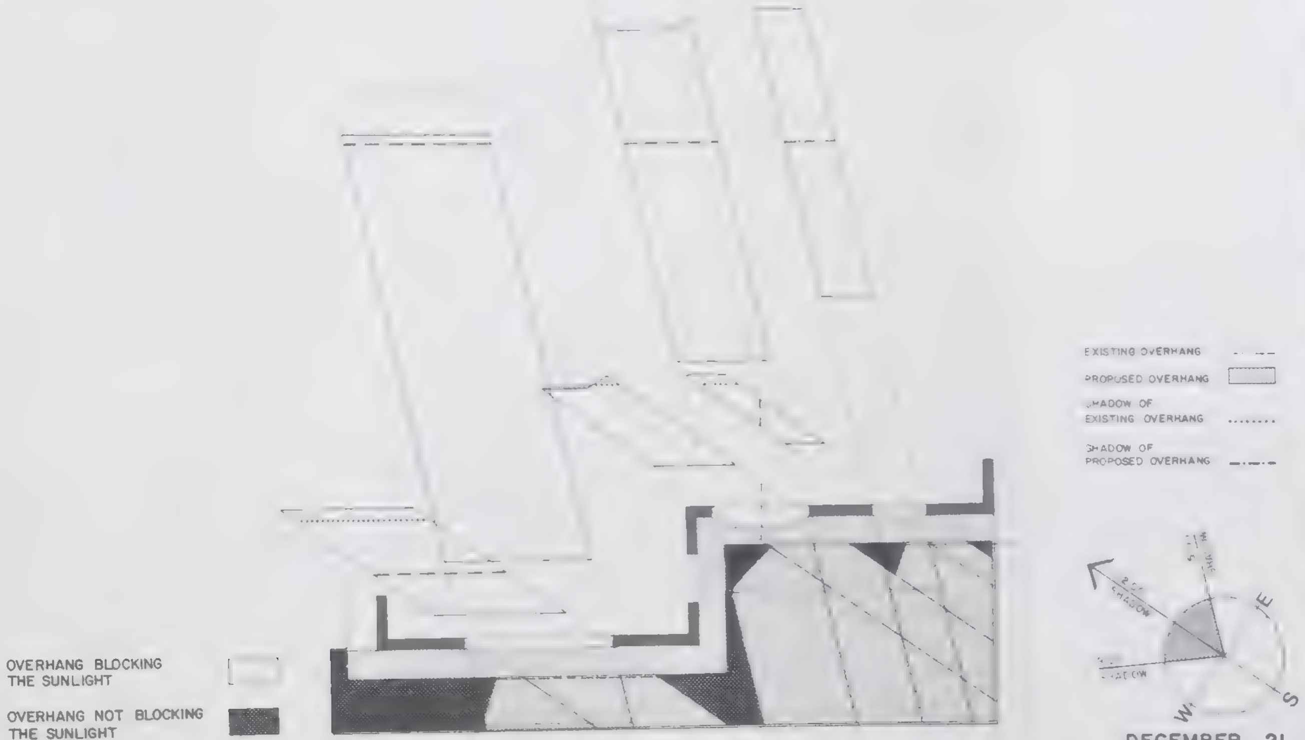
OVERHANG NOT BLOCKING THE SUNLIGHT ■


15 OF SHADOW
SHADOW
SHA
E
S
W

NOVEMBER 21

SHADOW PATTERN

TASK : 5 CONT..

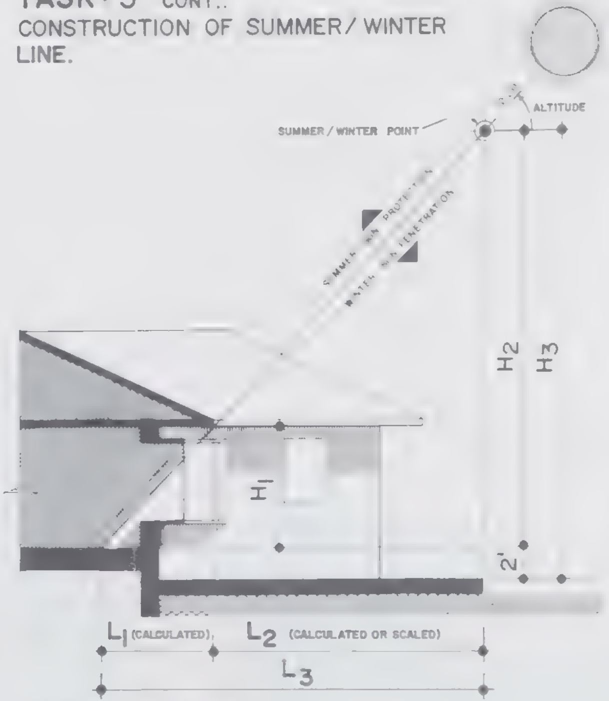

EXISTING OVERHANG
PROPOSED OVERHANG
SHADOW OF EXISTING OVERHANG
SHADOW OF PROPOSED OVERHANG
SHADOW
SHADOW
E
S
W
OVERHANG BLOCKING THE SUNLIGHT
OVERHANG NOT BLOCKING THE SUNLIGHT

DECEMBER 21

SHADOW PATTERN

TASK : 5 CONT..

CONSTRUCTION OF SUMMER/WINTER LINE.


SUMMER / WINTER POINT
ALTITUDE
SUMMER SUN PROTECTION
WINTER SUN PENETRATION
H2
H3
H1
2'
L1 (CALCULATED)
L2 (CALCULATED OR SCALED)
L3

SECTION AT AA

METHOD : 1

$L_3 = L_1 + L_2$

$$H_2 = \frac{L_3 \times H_1}{L_1}$$

L_1 CALCULATED $= 7 \cdot 5'$

L_2 CALCULATED OR SCALED $= 17 \cdot 8'$

L_3 $7 \cdot 5' + 17 \cdot 8'$ $= 25 \cdot 3'$

H_1 GIVEN $= 8 \cdot 0'$

H_2 $26 \cdot 98'$ SAY $= 27 \cdot 0'$

H_3 $27 \cdot 0' + 2 \cdot 0'$ $= 29 \cdot 0'$

METHOD : 2 (FROM THE TEMPLATE)

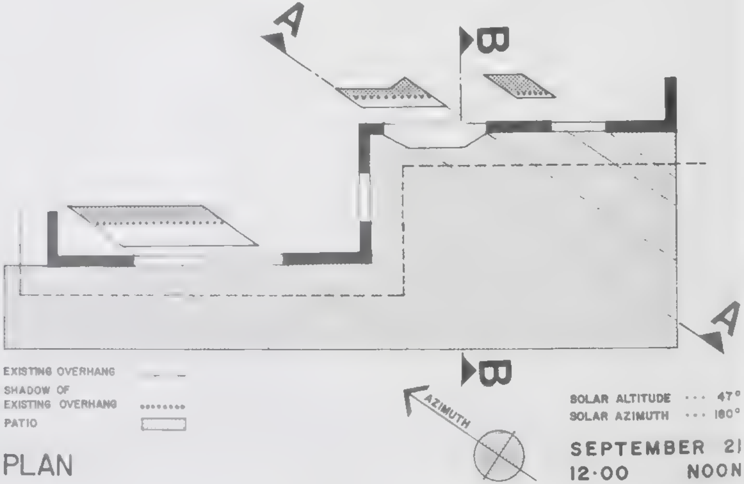
HEIGHT OF A POLE x COEFICIENT = LENGTH OF THE SHADOW

H_2 X COEFICIENT $= L_3$

$$H_2 = \frac{L_3}{\text{COEFICIENT}} = \frac{25 \cdot 3}{\cdot 932} = 27 \cdot 0'$$

HEIGHT OF THE SUMMER/WINTER POINT $= H_2 + 2 \cdot 0' = H_3$

$H_3 = 27 \cdot 0' + 2 \cdot 0' = 29 \cdot 0'$


A
B
B
A
AZIMUTH

EXISTING OVERHANG – – –
SHADOW OF EXISTING OVERHANG ········
PATIO ▭

PLAN

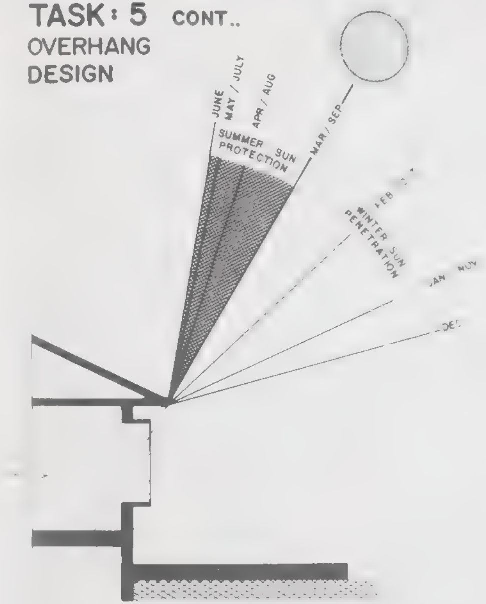
SOLAR ALTITUDE ··· 47°
SOLAR AZIMUTH ··· 180°

SEPTEMBER 21
12·00 NOON

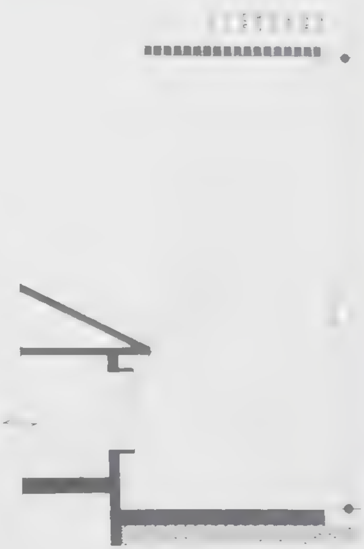
SHADOW PATTERN

TASK : 5 CONT..

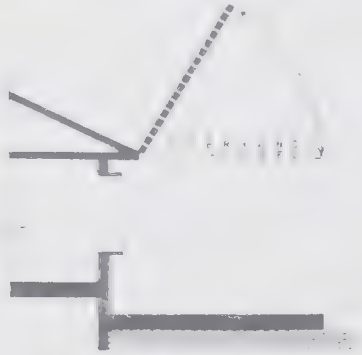
OVERHANG DESIGN


JUNE
MAY / JULY
APR / AUG
MAR / SEP
SUMMER SUN PROTECTION
FEB / OCT
WINTER SUN PENETRATION
JAN / NOV
DEC

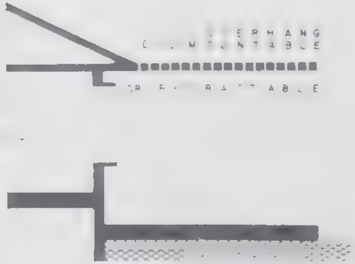
SECTION AT BB



SOLUTION : I



SOLUTION : 2


OVERHANG
COMFORTABLE

SOLUTION : 3

SHADOW PATTERN

THE ECOCHART IS AN ECOLOGICAL [illegible] OF:

1. A GRAPHIC REPRESENTATION AND DESCRIPTION OF THE EARTH'S SURFACE
   - TOPOGRAPHICAL RELIEF;
   - MAN-MADE FEATURES (ROADS, BUILDINGS, ETC.); AND,
   - NATURAL FEATURES (WATER, VEGETATION, ETC.).

SINCE CLIMATE HAS AN OBVIOUS AND IMPORTANT INFLUENCE ON ENERGY NEEDS, THE FOLLOWING ELEMENTS OF THE LOCAL (MICRO) CLIMATE ARE PARTICULARLY SIGNIFICANT:

2. MICRO-CLIMATIC DATA
   - AIR TEMPERATURE;
   - HOURS OF SUNSHINE;
   - DEGREE-DAYS;
   - PRECIPITATION;
   - RELATIVE HUMIDITY;
   - SOIL TEMPERATURE;
   - WIND VELOCITY AND DIRECTION;
   - SUN ANGLES AND SHADOWS; AND,
   - SUNRISE AND SUNSET.

NOTE:
- THIS DATA IS SHOWN FOR EVERY MONTH FOR TEN (10) YEAR AVERAGE, WHERE POSSIBLE.
- THE ECOCHART - GRAPHIC SUMMARY IS ENCLOSED AT THE END OF THE REPORT.
- FOR DETAILED DATA SEE APPENDICES...

AIR TEMPERATURE:

OUR LOCAL CLIMATE IS CHARACTERIZED BY WIDE VARIATIONS IN AIR TEMPERATURE BETWEEN SEASONS. THESE VARIATIONS PRODUCE MAJOR DIFFERENCES IN THE ENERGY REQUIREMENTS. MEAN MAXIMUM, MEAN MINIMUM, AND MEAN OF MEAN MAXIMUM AND MEAN MINIMUM OF EACH MONTH ARE EXPRESSED.

HOURS OF SUNSHINE:

THE INTENSITY AND AMOUNT OF SOLAR RADIATION DEPENDS UPON THE CLEARNESS OF THE ATMOSPHERE, I.E., CLOUD COVER, DEGREE OF OBSTRUCTION ON THE HORIZON, LATITUDE AND TIME OF THE YEAR. THE MEASUREMENT OF SUNSHINE TIME IS ABSOLUTELY ESSENTIAL FOR AN ACTIVE AND PASSIVE SOLAR-HEATING SYSTEM.

HEATING DEGREE-DAYS:

ARE THE NUMBER OF DEGREES WHEN THE DAILY AVERAGE TEMPERATURE IS BELOW 18 [illegible].

A DAY WITH AN AVERAGE TEMPERATURE OF 13°C HAS FIVE (5) HEATING DEGREE-DAYS (18 - 13 = 5) WHILE ONE WITH AN AVERAGE TEMPERATURE OF 18°C OR HIGHER HAS NONE. THE DEGREE-DAYS [illegible] A PERIOD OF DAYS REPRESENT THE TOTAL HEATING LOAD FOR THAT PERIOD. THE RELATIONSHIP BETWEEN DEGREE-DAYS AND FUEL CONSUMPTION IS LINEAR.

COOLING DEGREE-DAYS:

ARE THE NUMBER OF DEGREES WHEN THE DAILY AVERAGE TEMPERATURE IS ABOVE 18° CELSIUS.

A DAY WITH AN AVERAGE TEMPERATURE OF 23°C HAS FIVE (5) COOLING DEGREE-DAYS (23 - 18 = 5).

PRECIPITATION:

IS DEFINED AS WATER THAT FALLS ON THE EARTH'S SURFACE IN THE FORM OF RAIN, SNOW OR SLEET.

AMOUNT OF PRECIPITATION IS REQUIRED FOR THE PROPER DESIGN AND CONSTRUCTION OF A BUILDING (WATERPROOFING, INSULATION, ETC.).

LANDSCAPE DESIGN IS DIRECTLY RELATED TO PRECIPITATION.

SNOW AFFECTS ENERGY CONSUMPTION BY REFLECTING THE SUNLIGHT AND HEAT AT SOUTHERN EXPOSURES AND BY CREATING THERMAL INSULATION.

RAIN IS EXPRESSED IN MILLIMETRES (MM); SNOW IS EXPRESSED IN CENTIMETRES (CM); TOTAL PRECIPITATION IS EXPRESSED IN (MM). (RAIN PLUS THE WATER EQUIVALENT OF SNOW.)

RELATIVE HUMIDITY:

R/H IS THE PERCENTAGE OF WATER IN THE AIR AT PARTICULAR TEMPERATURE. SINCE THE AMOUNT OF WATER IN THE AIR IS DIRECTLY RELATED TO ITS THERMAL CONTENT, RELATIVE HUMIDITY PLAYS AN IMPORTANT ROLE IN THE DESIGN OF PASSIVE SOLAR HEATING/COOLING SYSTEMS.

IT IS EXPRESSED IN PERCENTAGE AND USUALLY MEASURED [illegible].

SOIL TEMPERATURE:

IT IS NECESSARY TO SURVEY THE SOIL TO DETERMINE ITS STRENGTH, BEARING CAPACITY AND TYPE. THESE CHARACTERISTICS VARY, EVEN WITHIN THE SAME SITE. AS SOIL TYPES VARY, SO DO THEIR THERMAL CHARACTERISTICS. THESE SHOULD BE STUDIED WHEN SPECIFYING INSULATION FOR A FOUNDATION, A SLAB ON A GRADE AND BASEMENT WALLS. GROUND HEAT STORAGE ACCUMULATED DURING THE SUMMER REDUCES THE HEAT LOSS FROM THE BASEMENT BY A DECLINING AMOUNT UNTIL FROST PENETRATES TO MAXIMUM DEPTH. SOIL TEMPERATURE IS TAKEN AT 10:00 A.M. AT 10 CM BELOW GROUND SURFACE.

WIND SPEED AND DIRECTION:

EVERYONE IS AWARE OF HOW MUCH COOLER IT FEELS OUTDOORS ON A WINDY DAY AS COMPARED TO WHEN THERE IS NO WIND, PARTICULARLY IN THE WINTER. THE SPEED, DIRECTION AND FREQUENCY OF SEASONAL WINDS AFFECT ENERGY REQUIREMENTS. A WIND SPEED INCREASE CAUSES A MORE RAPID RATE OF HEAT TRANSFER. WIND DATA CAN BE UTILIZED FOR WIND PROTECTION DESIGN IN THE WINTER MONTHS THROUGH VEGETATION, BUILDING ENTRANCES AND SITING OF INDIVIDUAL BUILDINGS, AND FOR COOLING EFFECTS IN THE SUMMER. WIND SPEED IS MEASURED IN KILOMETRES/HOUR IN 16 DIRECTIONS. (SEE APPENDIX C)

SUN ANGLES AND SHADOWS:

THE SUN'S POSITION IN THE [illegible] CALLED "SOLAR ALTITUDE" AND [illegible] 90 DEGREES (WHEN THE SUN IS [illegible] EAST TO WEST IS CALLED "SOLAR AZIMUTH" AND IS MEASURED [illegible] THE SUN ON THE HORIZON. IT EQUALS 0° AT NORTH [illegible] AND 360° AT NORTH TO COMPLETE THE FULL CIRCLE. [illegible] SPECIFIC DAY AND TIME.

SUN ANGLES DETERMINE THE LENGTH AND DIRECTION [illegible] OVERHANGS, SUN SCREENS, [illegible]

FOR A FAST SHADOW-CASTING CALCULATION, THE TEMPLATES HAVE BEEN PREPARED [illegible] INCLUDE NORTHERN AND SOUTHERN SLOPES UP TO 5%.

IF ONE WERE TO USE A STRI[illegible] FORM, THE RESULT WOULD BE A GIANT [illegible] ENERGY EFFICIENCY ARE TRYING TO [illegible] BY ARCHITECTURAL FORM. THERE IS SOME MERIT IN A TOWERING [illegible] AREA. TO BUILT A DENSE FOREST OF SUCH NEEDLES IS A PERVERSI[illegible]

ANOTHER REASON FOR TURNING [illegible] BELIEF THAT WE (HUMANS) CANNOT FUNCTION IN SUCH ENVIRONMENTS. THE "SCIENTIFIC OBSERVATION" OF THE BEHAVIOUR OF LEMMINGS, RATS AND PUBLIC HOUSING TENANTS [illegible] INTO AN ABSOLUTE TRUTH. ONLY A FEW DARE TO [illegible] CHALLENGE THIS "INDISPUTABLE" DICTUM.

THE FACT OF THE MATTER IS THAT SHELTER IS A PART OF MAN'S OVERALL SURVIVAL STRATEGY AND LIFE-STYLE. IT DIFFERS FROM PLACE TO PLACE, FROM CULTURE TO CULTURE. AN IROQUOIS WOULD BE INSANE [illegible]

IF WE WERE FORCED TO WINTER IN AN IGLOO, AND THE SAME WOULD HAPPEN TO AN INNUIT IN AN IROQUOIS LONG HOUSE. A PARISIAN, THOROUGHLY ENJOYING HIS LIFE LIVING IN AN APARTMENT IN THE MIDDLE OF THE CITY, WOULD DIE IF REPLANTED INTO NORTH AMERICAN SUBURBIA; CONVERSELY, A SUBURBAN FAMILY WOULD NEED EVEN MORE PSYCHIATRIC ASSISTANCE IF FORCED TO LIVE DOWNTOWN.

THUS, IT IS DOUBTFUL THAT HIGH OR SUPER DENSITIES ARE EVIL PER SE. THERE ARE SOCIETIES LIVING AND PROSPERING IN EXTREMELY HIGH DENSITIES. SUCH A LIFESTYLE IS A PRODUCT OF CIRCUMSTANCE: FIRST, IT HAS TO BE LEARNED AND THEN FIRMLY EMBEDDED IN THE CULTURE. THE LEARNING PROCESS, HOWEVER, IS SLOW AND REQUIRES MORE THAN ONE GENERATION TO TAKE HOLD. LIVING IN A SHOULDER-TO-SHOULDER SITUATION DEMANDS BEHAVIOURAL DISCIPLINE. BUT THIS IS, INDEED, A VERY HARD PROPOSITION TO SELL.

IN SUMMARY, THE ULTIMATE SOLUTION FOR AN ENERGY-EFFICIENT URBAN FORM IS NOT ACCEPTABLE FOR SOCIAL, CULTURAL, PSYCHOLOGICAL, BEHAVIOURAL AND OTHER REASONS. ON THE OTHER HAND, THE PRESENT

SUBURBAN DEVELOPMENTS ARE SO [illegible] LONGER. THE ERA OF ULTRA-LOW DENSITIES IS DEFINITELY OVER.

OBVIOUSLY, THE ONLY AVENUE [illegible] APPROACHED FROM A DIFFERENT ANGLE. WE [illegible] OF DENSITIES AND THEN ATTEMPT TO SQUEEZE IN [illegible] RATHER, WE SHOULD SET CERTAIN LEVELS OF [illegible] LIVING - AND INCREASE DENSITIES AS [illegible] TAKEN BY MANY PLANNERS AND ARCHITECTS. IN ADDITION, A NUMBER OF [illegible] HAVE BEEN BUILT BY IMAGINATIVE BUILDERS. CERTAIN RESULTS ARE EVEN [illegible]

IN FACT, IT HAS BEEN DEMONSTRATED THAT IT IS POSSIBLE TO IMPROVE WHAT WE [illegible] OF A FAMILY LIVING ENVIRONMENT AND SIMULTANEOUSLY INCREASE THE DENSITY OF THAT DEVELOPMENT. THE KEY TO THIS TYPE OF SUCCESS IS INNOVATIVE ARCHITECTURAL FORM.

LOW-PROFILE, 'GROUND-ORIENTED", MEDIUM-DENSITY DEVELOPMENTS WILL UNDOUBTEDLY BE THE TREND FOR THE REMAINDER OF THIS CENTURY. IN ADDITION, THIS WILL BE SPICED BY FREQUENT ATTEMPTS TO REVIVE THE CONCEPT OF AN OLD-FASHIONED NEIGHBOURHOOD IN TERMS OF PLACING GREATER EMPHASIS ON MIXED LAND USE AND ON THE CLOSE PROXIMITY OF DIFFERENT HUMAN ACTIVITIES AND LAND USES.

IT IS IMPORTANT TO BE AWARE THAT IN THIS TIME OF TRANSITION, THE SINGLE-FAMILY HOUSE IS BOUND TO GO THROUGH A SIMILAR PROCESS OF MUTATION AND TRANSFIGURATION, AS HAS THE FAMILY CAR. THE FUTURE CUSTOMER WOULD BE LOOKING FOR A COMFORTABLE, INTELLIGENTLY-DESIGNED PRODUCT WITH LOW ENERGY CONSUMPTION AND WITH MINIMAL MAINTENANCE AND UPGRADING. A BLOCK-LONG CAR IS PRACTICALLY EXTINCT. DOES THIS MEAN THAT LARGE HOUSES BUILT IN ULTRA-LOW DENSITY SUBDIVISIONS ARE ALSO DOOMED?

YES -- WITH QUALIFICATIONS.

THE MAINSTREAM WILL CERTAINLY BE HEADING TOWARD [illegible]. HOWEVER, TWO GROUPS OF BUYERS WILL FIND [illegible] MORE APPEALING:

- THERE WILL ALWAYS BE AN INTEREST IN HIGHLY VISIBLE AND [illegible] BY THE AFFLUENT SEGMENT OF SOCIETY; AND,
- THE IDEA OF SELF-SUFFICIENCY, REAL OR IMAGINED, WILL MOTIVATE ANOTHER [illegible] ACCOMMODATIONS WITH SUFFICIENT SURROUNDINGS TO GROW THEIR OWN [illegible].

POSSIBLY, A THIRD GROUP OF POTENTIAL BUYERS MIGHT BE CREATED BY A FAIRLY [illegible], BUT NEVERTHELESS, CONCEIVABLE CIRCUMSTANCE. THE GALLOPING COMMUNICATIONS REVOLUTION COULD POTENTIALLY TRANSFORM A SINGLE-FAMILY HOME INTO AN INFORMATION TERMINAL. WITH THE NECESSITY OF GOING TO WORK, SCHOOL, OR SHOPPING REMOVED, THERE WOULD BE PRACTICALLY NO REASON TO TRAVEL, EXCEPT PERHAPS FOR THE SHEER JOY OF IT, OR FOR RECREATION. SINCE COMMUTING MIGHT BE SUBSTITUTED BY

IMPROVED COMMUNICATION, THE MAJOR ARGUMENT AGAINST LOW DENSITY WOULD BE ELIMINATED. CERTAINLY, THIS NEWLY-CREATED FORM OF LIFESTYLE MIGHT BE CONSIDERED APPEALING BY SOME.

ALTHOUGH THERE IS LITTLE HOPE FOR SUBURBANIZATION OF THE TYPE AND SCALE WE HAVE EXPERIENCED DURING THE LAST THREE DECADES, THIS DOES NOT NECESSARILY FORECAST BAD TIMES FOR THE DEVELOPMENT INDUSTRY. ON THE CONTRARY. THE ERA OF A NEW PROSPERITY FOR THOSE WHO CAN INTELLIGENTLY INTERPRET THE IMPERATIVES OF OUR TIMES IS JUST COMMENCING.

A.I.A. Research Corp., Solar Dwelling Design Concepts, Washington: U.S. Government Printing Office, 1977

American Society of Landscape Architects Foundation, Landscape Planning for Energy Conservation, Reston, Va.: Environmental Design Press, 1977

Bennett, Robert, Sun Angles for Design, U.S.A., 1978

Berkowitz, M. K., Implementing Solar Technology in Canada: Summary, Department of Energy, Mines and Resources, 1978

Braden, Spruille, Graphic Standards of Solar Energy, [illegible]

Brampton Planning Department, Energy Conservation in Land Use Planning, [illegible] [illegible]

Bureau of Municipal Reaearch, Topic No. 3, What Can Municipalities Do About Energy? Toronto, March, 1978

Canada Mortgage and Housing Corporation, The Conservation of Energy in Housing, [illegible]

BIBLIOGRAPHY

Champlain Heights Development Group, Basic Guidelines for Energy Conservation in Community Planning and Building Design, Vancouver, 1979

Curtis, Fred (ed.), Considerations and Opportunities for Energy Conservation in Urban and Regional Planning. Conference Proceedings, March 9 - 11, 1979. Queen's University, Kingston Ontario

Egan, M. D., Concepts in Thermal Comfort. Englewood Cliffs, N. J.: Prentice-Hall, 1975

Energy, Mines and Resources Canada, Passive Solar Heating in Canada, A Discussion Paper, 1979

Environment Canada, Energy Conservation Through Land Use Decisions, March, 1976.

Ferrey, Steven, How Carter's Solar Program Could Eclipse the Cities, Planning, ASPO Magazine 44 (December, 1978): 20 - 23

Foster, Ruth, Landscaping That Saves Energy Dollars, New York: McKay, 1978

Griffin, C. W., Energy Conservation in Buildings: Techniques for Economical Design. The Construction Specifications Institute. Washington, D. C., 1974.

Hamilton-Wentworth, Regional Municipality of, Planning and Development Department, Energy Consideration in Urban and Regional Planning, January, 1978

Hix, John, "Energy Conse[illegible] 20 - 38

Hix, John, "Energy Considerations in the Planning o[illegible] 1978): 1 - 6

Hix, John, *Energy Demand for Future and* [illegible] Commission on Electric Power Planning, [illegible]

Hix, John and Linton, Karl, *"Frankel/Lambert" Energy* [illegible] Housing Department, Toronto; July, 1977

Hollands, K.G.T. and [illegible] *[illegible] Canada*, Un[illegible] Research Institute, Report No. 77-01, February, 1977

Housing and Urban De[illegible] *Guide to Energy Efficien[illegible]* [illegible]

Linton, K. J., "Case [illegible] 42 - 47

Mazria, Edward. *The Passive Solar Energy Book*, Emmaus, Pa.: Rodale Press, 1979

Middleton Associates, *Urban Form and Energy Consumption*. Prepared for The Ministry of State for Urban Affairs, Toronto; March, 1979

Minnesota, University of, The Underground Space Centre. *Earth Sheltered Housing Design Guidelines, Examples and References.*, 1979

Morris, David, "Solar Energy is Really Power for the People", *Planning*, ASPO Magazine 42 (September, 1976): 16 - 20

[illegible]ena, D., "Site Design: Can It Really Save Energy?", *Planning*, ASPO Magazine 43 (December, 1977): 22

Nadler, Arnold D., "Planning Aspects of Direct Solar Energy Generation", *Journal of the American Institute of Planners* 43 (October, 1977): 336

National Research Council of Canada, *Measures for Energy Conservation in New Buildings*, 1978

NATIONAL RESEARCH COUNCIL OF CANADA, *TABLES OF SOLAR ALTITUDE, AZIMUTH, INTENSITY AND HEAT GAIN FACTORS FOR LATITUDES FROM 43 TO 55 DEGREES NORTH*, TECHNICAL PAPER NO. 243, APRIL, 1967

NATIONAL RESEARCH COUNCIL, *SOLAR RADIATION CONSIDERATIONS IN BUILDING PLANNING AND DESIGN*, PROCEEDINGS OF A WORKING CONFERENCE, WASHINGTON, D.C.: NATIONAL ACADEMY OF SCIENCES, 1976

OLGYAY, VICTOR, *DESIGN WITH CLIMATE. BIOCLIMATIC APPROACH TO ARCHITECTURAL REGIONALISM*. PRINCETON: PRINCETON UNIVERSITY PRESS, 1963

ONTARIO MINISTRY OF ENERGY, *IS YOUR HEATING BILL GOING THROUGH THE ROOF?* (PAMPHLET)

ONTARIO MINISTRY OF ENERGY, *BIBLIOGRAPHY, ENERGY EFFICIENT COMMUNITY PLANNING*, DECEMBER, [illegible]

ONTARIO MINISTRY OF ENERGY, *SUBDIVISIONS AND SUN* - THREE DESIGN STUDIES, SEPTEMBER [illegible]

ONTARIO MINISTRY OF ENERGY, *PERSPECTIVES ON ACCESS TO SUNLIGHT*, TORONTO, MAY, [illegible]

ONTARIO MINISTRY OF ENERGY, *TURN ON THE SUN*, TORONTO, SEPTEMBER, 1977

Ontario Ministry of Housing, "Ontario Looks at District Heating", Housing Ontario 22 (July, 1978)

Ontario Ministry of Housing, "Subdivision Design for Energy Conservation", Housing Ontario 22 (July 1, 1978): 15

[illegible], Energy Conservation and Building Design. N.R.C.C. No. 110. Ottawa; May, 1976

Steadman, Philip. Energy, Environment and Building. [illegible] Cambridge University Press, 1975

"Then in Toronto [illegible] Energy", The Canadian Architect, (March, 1977): 48 - 50

U. S. Department of Energy, Protecting Solar Access for Residential Development, A Guidebook for Planning Officials, May 1979

U. S. Department of Energy, Site Planning for Solar Access, A Guidebook for Residential Developers and Site Planners, September 1979

Webster, Bayard, "Age-old Search: Wood Shortage Spurred Greeks to Use Solar Power", The Globe and Mail (28 May 1979)

A - ● AIR TEMPERATURE
- ● HOURS OF SUNSHINE
- ● DEGREE-DAYS: HEATING AND COOLING
- ● PRECIPITATION
- ● RELATIVE HUMIDITY
- ● SOIL TEMPERATURE
- ● WIND SPEED, DIRECTION AND HOURS
- ● SOLAR ALTITUDE AND AZIMUTH
- ● SUNRISE AND SUNSET

B - ● SHADOW CASTING FORMULAS

C - ● WIND SPEED AND DIRECTION HOURLY

APPENDICES

- AIR TEMPERATURE
- HOURS OF SUNSHINE
- DEGREE-DAYS: HEATING AND COOLING
- PRECIPITATION
- RELATIVE HUMIDITY
- SOIL TEMPERATURE
- WIND SPEED, DIRECTION AND HOURS
- SOLAR ALTITUDE AND AZIMUTH
- SUNRISE AND SUNSET

APPENDIX A

AIR TEMPERATURE: DEGREES CELSIUS (°C)

		69	70	71	972	973	1974	1975	1976	1977	1978	MEAN
JANUARY	Mean Maximum	- .8	- .4	- 3.8	- 0.7	- 0.3	- 1.1	0.8	- 4.3	- 8.2	- 4.5	- 2.7
	Mean Minimum	- .2	-1 .9	-11.7	- 9.6	- 7.4	- 8.6	- 6.3	-13.8	-15.3	-11.5	-10.5
	Mean	- .5	- .7	- 7.7	- 5.1	- 3.8	- 4.8	- 2.7	- 9.1	-11.8	- 8.0	- 6.[illegible]
FEBRUARY	Mean Maximum	- .1	- .6	- 1.5	- 2.4	- 2.8	- 2.6	- 1.0	.8	- 2.5	- 5.6	- 1.[illegible]
	Mean Minimum	- .4	- .8	- 7.9	- 1.4	- 1.5	-10.8	- 6.2	- .8	- 9.1	-15.0	- 9.4
	Mean	- .2	- .7	- 4.7	- 6.9	- 7.2	- 6.7	- 3.6	- .0	- 5.8	-10.3	- 5.5
MARCH	Mean Maximum	.1	.6	0.8	0.4	7.2	3.3	1.1	5.8	7.2	0.3	[illegible]
	Mean Minimum	- .3	- .5	- 6.0	- 6.9	- 0.3	- 4.4	- 5.9	- .2	- 2.4	- .2	- 4.[illegible]
	Mean	- .6	- .9	- 2.6	- 3.2	3.4	- 0.6	- 2.4	1.3	2.4	- 4.0	- 0.7
APRIL	Mean Maximum	1 .2	1 .4	10.7	8.7	0.7	12.7	7.9	1 .5	13.3	9.7	11.2
	Mean Minimum	.4	.3	- 0.1	- 1.2	2.1	2.1	- 1.1	.3	2.1	0.0	1.1
	Mean	.3	.4	5.3	3.8	6.4	7.4	3.4	7.9	7.7	4.9	6.2
MAY	Mean Maximum	1 .7	1 .3	18.6	9.6	5.7	15.8	21.8	16.5	21.8	18.4	1 .4
	Mean Minimum	.2	.4	.3	8.7	6.4	5.3	10.4	5.7	8.7	7.4	7.4
	Mean	1 .4	1 .9	1 .5	4.2	1.1	10.6	16.1	11.1	15.2	12.9	1 .9
JUNE	Mean Maximum	2 .9	2 .2	2 .9	1.0	4.6	22.7	23.6	25.3	23.0	24.0	23.5
	Mean Minimum	1 .6	1 .7	14.3	1.5	3.9	12.6	14.3	14.1	11.4	11.3	13.0
	Mean	1 .3	1 .9	1 .6	6.3	9.2	17.7	18.9	19.7	17.2	17.7	[illegible]
JULY	Mean Maximum	2 .2	2 .7	2 .9	5.9	6.9	26.4	27.0	24.7	26.6	26.3	26.3
	Mean Minimum	1 .8	1 .0	14.2	5.5	5.5	14.7	15.2	14.3	15.7	13.8	15.[illegible]
	Mean	2 .5	2 .9	20.1	0.8	1.2	20.6	21.1	19.5	21.2	20.1	20.[illegible]
AUGUST	Mean Maximum	2 .3	2 .7	26.1	4.3	7.7	26.1	24.6	24.2	24.2	26.0	25.9
	Mean Minimum	1 .6	1 .3	1 .3	4.3	6.6	14.9	14.8	1 .2	13.6	14.5	14.9
	Mean	2 .4	2 .5	1 .7	9.3	2.2	20.5	19.7	1 .7	18.9	20.3	20.4
SEPTEMBER	Mean Maximum	2 .3	2 .9	2 .5	1.4	2.4	19.4	18.0	1 .5	19.9	21.0	20.7
	Mean Minimum	1 .4	1 .7	1 .9	1.2	0.2	8.8	8.6	8.8	12.3	10.1	10.[illegible]
	Mean	1 .3	1 .3	1 .7	6.3	6.3	14.1	13.3	13.7	16.1	15.6	15.[illegible]
[illegible]	Mean Maximum	.4	1 .3	1 .9	1.4	5.9	13.1	15.2	10.7	13.3	13.1	14.0
	Mean Minimum	.0	.2	.6	2.2	6.7	2.7	5.6	2.3	4.3	3.8	5.0
	Mean	.2	.8	.3	6.8	1.3	7.9	10.4	6.5	8.8	8.5	9.[illegible]
NOVEMBER	Mean Maximum	[illegible]	[illegible]	.9	4.1	7.0	[illegible]	11.4	3.5	7.3	7.6	7.1
	Mean Minimum	[illegible]	[illegible]	.8	1.3	0.6	[illegible]	[illegible]	- 4.1	1.3	- 1.3	0.1
	Mean	[illegible]	[illegible]	.1	1.4	3.8	[illegible]	7.1	- 0.3	4.3	3.2	3.6
DECEMBER	Mean Maximum	[illegible]	[illegible]	.8	[illegible]	[illegible]	[illegible]	[illegible]	- .9	- 0.6	1.2	0.4
	Mean Minimum	[illegible]	[illegible]	- .4	- [illegible]	- [illegible]	- 4.1	- 7.5	-11.4	- 6.8	- 5.9	- 6.5
	Mean	[illegible]	[illegible]	- [illegible]	- [illegible]	- [illegible]	- 1.4	- 3.7	- 7.2	- 3.7	- 2.4	- 3.1
YEARLY	Mean Maximum											12.2
	Mean Minimum											3.2
	Mean											7.5

SOURCE: Environment Canada

HOURS OF SUNSHINE

		1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	MEAN
JANUARY	Possible											290.6
	Actual	96.3	83.0	92.7	101.9	129.0	56.4	86.5	103.6	92.5	79.4	95.2
FEBRUARY	Possible											292.9
	Actual	132.0	129.4	68.7	97.8	104.1	142.7	72.3	113.3	110.3	Missing	107.8
MARCH	Possible											368.1
	Actual	162.2	141.6	136.0	119.6	96.9	125.7	144.5	121.5	181.1	Missing	136.6
APRIL	Possible											413.8
	Actual	172.8	187.7	188.7	193.5	181.2	185.8	213.6	240.1	220.1	Missing	197.0
MAY	Possible											452.6
	Actual	250.0	189.4	266.1	250.1	156.5	226.7	257.2	209.9	305.5	Missing	237.6
JUNE	Possible											458.2
	Actual	179.7	258.2	275.4	173.2	239.2	[illegible]	[illegible]	[illegible]	303.7	272.3	250.5
JULY	Possible											464.7
	Actual	281.2	228.0	289.3	264.8	294.7	329.4	346.5	257.7	294.0	288.7	287.4
AUGUST	Possible											432.1
	Actual	288.6	289.9	300.5	215.8	269.8	272.2	223.4	283.6	269.7	261.2	267.5
SEPTEMBER	Possible											374.5
	Actual	135.4	133.6	137.9	166.7	199.5	165.4	168.4	202.6	121.2	187.1	161.8
OCTOBER	Possible											342.3
	Actual	132.8	85.8	131.4	108.1	145.6	185.1	148.9	132.1	177.6	147.1	139.4
NOVEMBER	Possible											291.5
	Actual	76.2	63.8	79.8	53.8	71.0	79.1	97.2	120.8	34.1	111.2	78.7
DECEMBER	Possible											280.3
	Actual	90.6	76.2	49.9	63.1	39.6	63.0	67.7	67.4	103.7	65.2	68.6
YEARLY	Possible											4,461.6
	Actual											2,028.1

SOURCE: Royal Botanical Garden

HEATING DEGREE-DAYS (>18°C)

MONTH	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	MAX.	MIN.	MEAN 10 YEARS
JANUARY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	641.8	[illegible]	922.7	806.7	922.7	641.8	762.6
FEBRUARY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	667.6	792.5	792.5	579.6	661.5
MARCH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	518.5	482.7	680.8	680.8	452.2	580.0
APRIL	323.1	322.5	383.5	428.0	348.4	320.9	439.6	308.1	311.6	394.7	439.6	308.1	358.0
MAY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	215.9	119.1	180.8	236.3	94.5	173.5
JUNE	64.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	54.2	53.1	80.2	18.7	43.7
JULY	11.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.3	15.3	22.0	2.7	9.1
AUGUST	0.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	33.6	31.6	2.3	33.6	0.5	14.7
SEPTEMBER	74.7	65.9	61.5	76.4	103.3	130.8	141.3	121.1	75.2	90.8	141.3	61.5	94.1
OCTOBER	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	354.9	284.0	295.6	354.9	153.8	265.3
NOVEMBER	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	548.8	411.0	446.2	548.8	327.3	431.9
DECEMBER	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	780.7	672.1	631.9	780.7	566.5	652.6
YEARLY	[illegible]	[illegible]	[illegible]	4326.4	[illegible]	4049.4	3840.6	4328.7	4039.1	4390.7	4390.7	3840.6	4047.0

SOURCE: Environment Canada

COOLING DEGREE-DAYS (< 18°C)

	1976	1977	1978	1979	MAX.	MIN.	MEAN 4 YEARS
JANUARY	-	-	-	-	-	-	-
FEBRUARY	-	-	-	-	-	-	-
MARCH	-	-	-	-	-	-	-
APRIL	6.8	2.3	-	-	6.8	2.3	4.6
MAY	-	34.3	23.5	11.4	34.3	11.4	23.0
JUNE	71.3	31.8	44.3	37.8	71.3	31.8	46.3
JULY	54.7	105.0	78.9	97.9	105.0	54.7	84.1
AUGUST	55.9	58.3	75.4	51.0	75.0	51.0	60.2
SEPTEMBER	18.1	19.7	18.1	19.7	19.7	18.1	18.9
OCTOBER	-	-	-	5.4	5.4	5.4	5.4
NOVEMBER	-	-	-	-	-	-	-
DECEMBER	-	-	-	-	-	-	-
YEARLY	206.8	251.4	240.2	223.2	317.5	174.7	242.5

SOIL TEMPERATURE °C AM - 10 CM BELOW GROUND SURFACE

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	MEAN
JANUARY				1.3	0.5	1.2	1.4	1.2	- 0.3	0.7	0.9
FEBRUARY				0.1	0.6	0.7	0.6	1.7	- 1.1	0.3	0.4
MARCH				- 0.2	3.3	1.9	1.2	3.0	1.0	0.2	1.5
APRIL				3.3	7.5	6.7	4.8	8.3	7.3	4.0	6.0
MAY				12.4	11.9	11.7	13.6	11.8	13.4	10.8	12.2
JUNE				17.1	19.0	17.1	19.1	18.6	17.6	17.1	17.9
JULY				21.1	22.1	19.9	21.4	20.3	21.3	20.3	20.9
AUGUST				20.8	21.4	20.5	21.0	20.3	20.8	20.7	20.9
SEPTEMBER				18.8	18.6	16.7	16.3	16.8	18.8	17.7	17.7
OCTOBER				11.2	13.4	10.5	12.7	10.7	12.2	12.3	12.0
NOVEMBER				6.2	7.2	7.6	8.9	4.3	8.8	7.8	7.3
DECEMBER				2.4	3.1	2.9	3.1	0.7	3.4	2.5	2.6
YEARLY MEAN				9.5	10.8	9.8	10.3	9.8	10.3	9.5	10.0

SOURCE: Royal Botanical Gardens

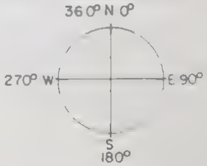
WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION (AVERAGE 1976 – 1979).

	NORTH		NNE		NE		ENE		EAST		ESE		SE		SSE		SOUTH		SSW		SW		WSW		WEST		WNW		NW		NNW	
	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS
JANUARY	16	18	21	[illegible]	[illegible]	[illegible]	25	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15	[illegible]
FEBRUARY	14	33	16	33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19	[illegible]	17	17
MARCH	17	11	16	16	21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	28	14	12
APRIL	16	38	18	35	23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	102	[illegible]	[illegible]	[illegible]	50	19	33
MAY	15	27	19	49	19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	56	17	24
JUNE	12	29	14	36	16	64	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	55	14	16
JULY	12	31	14	30	15	54	[illegible]	[illegible]	[illegible]	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	44	16	26
AUGUST	11	27	12	33	13	[illegible]	[illegible]	[illegible]	12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	49	11	27
SEPTEMBER	10	35	13	35	15	68	16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	32	15	28
OCTOBER	15	35	15	45	18	70	[illegible]	[illegible]	[illegible]	[illegible]	11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18	50	16	35	18	28
NOVEMBER	15	12	14	26	17	46	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13	14
DECEMBER	18	19	14	19	18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	32	17	14
[illegible] TOTAL HRS	14	315	16	378	18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16	262
	NORTH		NNE		NE		ENE		EAST		ESE		SE		SSE		SOUTH		SSW		SW		WSW		WEST		WNW		NW		NNW	

SOLAR ALTITUDE AND AZIMUTH FOR 43° NORTH ALTITUDE - HAMILTON

MONTHS	0900 HOURS Solar ALT.°	0900 HOURS Solar AZIM.°	1000 HOURS Solar ALT.°	1000 HOURS Solar AZIM.°	1200 HOURS Solar ALT.°	1200 HOURS Solar AZIM.°	1400 HOURS Solar ALT.°	1400 HOURS Solar AZIM.°	1500 HOURS Solar ALT.°	1500 HOURS Solar AZIM.°
JANUARY 21	14.6	136.6	21.2	149.7	27.0	180.0	21.2	210.3	14.6	223.4
FEBRUARY 21	22.3	131.3	29.6	145.6	36.2	180.0	29.6	214.4	22.3	228.7
MARCH 21	31.1	124.3	39.3	139.8	47.0	180.0	39.3	220.2	31.1	235.7
APRIL 21	40.1	115.2	49.3	131.4	58.6	180.0	49.3	228.6	40.1	244.8
MAY 21	46.0	107.0	55.9	123.0	67.0	180.0	55.9	237.0	46.0	253.0
JUNE 21	[illegible]	[illegible]	[illegible]	114.7	70.4	180.0	58.5	241.3	48.2	256.9
JULY 21	46.4	106.3	56.4	122.3	67.6	180.0	56.4	237.7	46.4	253.7
AUGUST 21	40.6	[illegible]	[illegible]	[illegible]	59.3	180.0	49.8	229.2	40.6	245.5
SEPTEMBER 21	31.1	124.3	39.3	139.8	47.0	180.0	39.3	220.2	31.1	235.7
OCTOBER 21	22.6	131.1	29.9	145.5	36.5	180.0	29.9	214.5	22.6	228.9
NOVEMBER 21	14.8	[illegible]	21.4	149.6	27.2	180.0	21.4	210.4	14.8	223.5
DECEMBER 21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	180.0	18.0	208.8	11.7	221.5

SOURCE: National Research Council of Canada



SUNRISE AND SUNSET

MONTH	SUNRISE	SUNSET
JANUARY 21	7:46	17:18
FEBRUARY 21	7:11	17:58
MARCH 21	6:24	18:32
APRIL 21	5:31	19:09
MAY 21	4:52	19:41
JUNE 21	4:41	20:02
JULY 21	4:58	19:54
AUGUST 21	5:31	19:14
SEPTEMBER 21	6:05	18:21
OCTOBER 21	6:40	17:30
NOVEMBER 21	7:19	16:52
DECEMBER 21	7:48	16:48

- All times in Eastern Standard Time.
- For Daylight Saving Time: From last Sunday of April to last Sunday of October, add one hour.

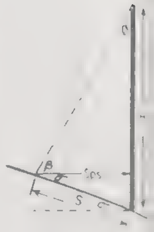
SHADOW CASTING FORMULAS

APPENDIX B

Date JANUARY 21

09:00 & 15:00 hours

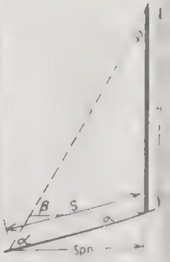
SLOPE h	Tang⁻¹	$\angle\sigma$	$\angle\beta$	$\angle\alpha = \angle\beta \pm \angle\sigma$	$\angle\phi$	Sin ϕ	Sin α	$S=\frac{H\cdot\sin\phi}{\sin\alpha}$	Cos σ	Sps or Spn
0 %	0.00	0° 00 00"	[illegible]	[illegible]	[illegible]	[illegible]	.2520694	3.8390	1·000 0000	Sp 3.839
1 %	0.01	0° 34 20"	"	[illegible]	"	"	.2617213	3.6974	0·999 9501	Sps 3.697
				[illegible]			.2423923	3.9923		Spn 3.992
2 %	0.02	1° 08 40"	"	[illegible]	"	"	.2713471	3.5663	0·999 8005	Sps 3.566
				[illegible]			[illegible]	4.1588		Spn 4.158
3 %	0.03	1° 43 00"	"	[illegible]	"	"	.2809924	3.4439	0·999 5497	Sps 3.442
				12 52 50			0.2229193	4.3411		Spn 4.340
4 %	0.04	2° 17 30"	"	[illegible]	"	"	[illegible]	3.3305	0·999 2002	Sps 3.328
				12 18 30			[illegible]	4.5396		Spn 4.536
5 %	0.05	2° 51 40"	"	17 27 40	"	"	0.3000584	3.2251	0·998 7535	Sps 3.221
				[illegible]			0.2034519	4.7564		Spn 4.750



(Southern Slope

10:00 & 14:00 hours

SLOPE h	Tang⁻¹	$\angle\sigma$	$\angle\beta$	$\angle\alpha = \angle\beta \pm \angle\sigma$	$\angle\phi$	Sin ϕ	Sin α	$S=\frac{H\cdot\sin\phi}{\sin\alpha}$	Cos σ	Sps or Spn
0 %	0.00	0° 00 00"	[illegible]	21° 12' 00"	68° 48'	0.9323238	0.3616246	2.5782	1·000 0000	Sp 2.578
1 %	0.01	0° 34 20"	"	21 46 20	"	"	0.3709176	2.5162	0·999 9501	Sps 2.516
				[illegible]			.3522954	2.6464		Spn 2.646
2 %	0.02	1° 08 40	"	[illegible]	"	"	0.3801737	2.4524	0·999 8005	Sps 2.452
				[illegible]			0.3429311	2.7187		Spn 2.718
3 %	0.03	1° 43 00"	"	[illegible]	"	"	.3894365	2.3940	0·999 5497	Sps 2.393
				[illegible]			.3334869	2.7957		Spn 2.794
4 %	0.04	2° 17 30"	"	[illegible]	"	"	[illegible]	2.3389	0·999 2002	Sps 2.337
				[illegible]			[illegible]	2.8770		Spn 2.875
5 %	0.05	2° 51 40"	"	[illegible]	"	"	[illegible]	2.2867	0·998 7535	Sps 2.284
				[illegible]			[illegible]	2.9632		Spn 2.953



(Northern Slope

12:00 hours

SLOPE h	Tang⁻¹	$\angle\sigma$	$\angle\beta$	$\angle\alpha = \angle\beta \pm \angle\sigma$	$\angle\phi$	Sin ϕ	Sin α	$S=\frac{H\cdot\sin\phi}{\sin\alpha}$	Cos σ	Sps or Spn
0 %	0.00	0° 00 00"	[illegible]	27° 00' 00"	[illegible]	[illegible]	[illegible]	1.9626	1·000 0000	Sp 1.962
1 %	0.01	0° 34 20"	"	27 34 20	"	"	[illegible]	1.9250	0·999 9501	Sps 1.925
				26 25 40			[illegible]	2.0019		Spn 2.001
2 %	0.02	1° 08 40"	"	28 8 40	"	"	[illegible]	1.8889	0·999 8005	Sps 1.888
				[illegible]			[illegible]	2.0431		Spn 2.043
3 %	0.03	1° 43 00"	"	28 43 10	"	"	[illegible]	1.8543	0·999 5497	Sps 1.854
				25 16 50			[illegible]	2.0864		Spn 2.085
4 %	0.04	2° 17 30"	"	29 17 30	"	"	[illegible]	1.8211	0·999 2002	Sps 1.820
				[illegible]			[illegible]	2.1316		Spn 2.130
5 %	0.05	2° 5 40"	"	[illegible]	"	"	[illegible]	1.7895	0·998 7535	Sps 1.787
				[illegible]			[illegible]	2.1788		Spn 2.176

FORMULA

$\angle\alpha = \angle\beta \pm$

$S = \frac{H\cdot\sin\phi}{\sin\alpha}$

Sps or Spn = S·COS σ

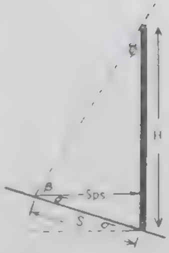
For Slopes

Sps or Spn = $\frac{[illegible]}{\sqrt{100^2+h^2}}$

Date FEBRUARY 1

hours 09:00 & 15:00

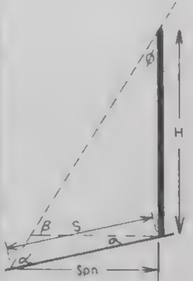
PE	Tang $^{-1}$	$\angle\sigma$	$\angle\beta$	$\angle\alpha = \angle\beta \pm \angle\sigma$	$\angle\phi$	$\sin\phi$	$\sin\alpha$	$S=\frac{H\cdot\sin\phi}{\sin\alpha}$	$\cos\sigma$	Sps or Spn
%	0·00	0° 00' 00"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
%	0·01	0° 34' 20"	"	[illegible] [illegible]	"	"	[illegible] [illegible]	[illegible] [illegible]	[illegible]	Sps [illegible] Spn [illegible]
%	0·02	1° 08' 40"	"	[illegible] [illegible]	"	"	[illegible] [illegible]	[illegible] [illegible]	[illegible]	Sps [illegible] Spn [illegible]
3 %	0·03	1° 43' 10"	"	[illegible] [illegible]	"	"	[illegible] [illegible]	[illegible] [illegible]	[illegible]	Sps [illegible] Spn [illegible]
%	0·04	2° 17' 30"	"	[illegible] [illegible]	"	"	[illegible] [illegible]	[illegible] [illegible]	[illegible]	Sps [illegible] Spn [illegible]
5 %	0·05	2° 51' 40"	"	[illegible] [illegible]	"	"	[illegible] [illegible]	[illegible] [illegible]	[illegible]	Sps [illegible] Spn [illegible]



(Southern Slope)

hours 10:00 & 14:00

OPE	Tang $^{-1}$	$\angle\sigma$	$\angle\beta$	$\angle\alpha = \angle\beta \pm \angle\sigma$	$\angle\phi$	$\sin\phi$	$\sin\alpha$	$S=\frac{H\cdot\sin\phi}{\sin\alpha}$	$\cos\sigma$	Sps or Spn
%	0·00	0° 00' 00"	29° 36'	29° 36' [illegible]	[illegible] 24'	[illegible]	[illegible]	[illegible]	[illegible]	Sp 1.[illegible]
%	0·01	0° 34' 20"	"	30 1 [illegible] 29 1 4[illegible]	"	"	[illegible] [illegible]	1.[illegible] 1.[illegible]	[illegible]	Sps 1.[illegible] Spn 1.[illegible]
%	0·02	1° 08' 40"	"	3[illegible] 44 4 28 27 [illegible]	"	"	[illegible] [illegible]	[illegible] 1.[illegible]	[illegible]	Sps 1.[illegible] Spn [illegible]
%	0·03	1° 43' 10"	"	32 19 1[illegible] 27 [illegible]	"	"	0.5196091 0.4[illegible]	1.6727 [illegible]	0·999 5497	Sps [illegible] Spn 1.[illegible]
%	0·04	2° 17' 30"	"	3[illegible] 53 30 27 18 30	"	"	0.5283149 [illegible]	1.6458 [illegible]	0·999 2002	Sps [illegible] Spn [illegible]
%	0·05	2° 51' 40"	"	[illegible] 41 27 44 30	"	"	[illegible] [illegible]	[illegible] 1.662	[illegible]	Sps 1.616 Spn 1.660



(Northern Slope)

hours 12:00

PE	Tang $^{-1}$	$\angle\sigma$	$\angle\beta$	$\angle\alpha = \angle\beta \pm \angle\sigma$	$\angle\phi$	$\sin\phi$	$\sin\alpha$	$S=\frac{H\cdot\sin\phi}{\sin\alpha}$	$\cos\sigma$	Sps or Spn
%	0·00	0° 00' 00"	36° 12'	36° 12' 00"	53° 48'	0.8069603	[illegible]	1.3663	[illegible]	Sp 1.366
%	0·01	0° 34' 20"	"	36 46 20 35 37 40	"	"	0.[illegible]3 0.[illegible]1	1.34[illegible] 1.3849	0·999 9[illegible]	Sps 1.348 Spn 1.385
%	0·02	1° 08' 40"	"	37 2 40 35 3 20	"	"	[illegible]53 [illegible]4	1.3303 1.4049	0·999 8005	Sps 1.330 Spn 1.40[illegible]
%	0·03	1° 43' 10"	"	37 55 1[illegible] 34 28 5[illegible]	"	"	0.614[illegible]30 [illegible]	1.3131 1.4254	0·999 549[illegible]	Sps 1.31[illegible] Spn 1.4[illegible]5
%	0·04	2° 17' 30"	"	38 29 30 33 54 30	"	"	[illegible]8 [illegible]8	1.2965 1.44[illegible]	0·99[illegible]2002	Sps 1.296 Spn 1.44[illegible]
%	0·05	2° 51' 40"	"	39 3 40 33 20 20	"	"	0.[illegible]31459 0.54[illegible]5903	1.2[illegible] 1.46[illegible]3	0·998 [illegible]35	Sps [illegible]79 Spn 1.4[illegible]

FORMULA

$$\angle\alpha = \angle\beta \pm \angle\sigma$$

$$S = \frac{H\cdot\sin\phi}{\sin\alpha}$$

$$\text{Sps or Spn} = S\cdot\cos\sigma$$

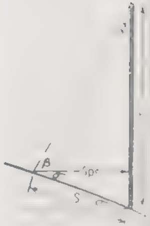
For Slopes h > 5%

$$\text{Sps or Spn} = \frac{100\cdot S}{\sqrt{100^2 + h^2}}$$

Date MARCH 21

hours 09:00 & 15:00

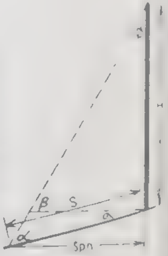
SLOPE	Tang⁻¹	∠σ	∠β	∠α = ∠β ± ∠σ	∠φ	Sin φ	Sin α	S = H·Sin φ / Sin α	Cos σ	Sps or Spn
0 %	0.00	0° 00' 00"	[illegible]	[illegible]	[illegible]	0.8563671	0.5165333	1.6577	1·000 0000	Sp 1.657
[illegible]	[illegible]	[illegible]	"	31 40 20	"	"	0.5250591	[illegible]	0·999 9501	Sps 1.630
				[illegible]			[illegible]	[illegible]		Spn 1.686
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	0·999 8005	Sps 1.605
				[illegible]			[illegible]	1.7148		Spn 1.714
3 %	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"	[illegible]	1.5798	0·999 5497	Sps 1.579
				[illegible]			[illegible]	1.7453		Spn 1.744
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"	[illegible]	1.5558	0·999 2002	Sps 1.554
				28 48 30			[illegible]	[illegible]		Spn 1.776
[illegible]	[illegible]	[illegible]	[illegible]	33 57 40	[illegible]	"	0.5586301	1.5328	0·998 7535	Sps 1.530
				[illegible]			[illegible]	1.8097		Spn 1.807



(Southern S[illegible]pe

hours 10:00 & 14:00

SLOPE	Tang⁻¹	∠σ	∠β	∠α = ∠β ± ∠σ	∠φ	Sin φ	Sin α	S = H·Sin φ / Sin α	Cos σ	Sps or Spn
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.6333809	1.2218	1·000 0000	Sp 1.221
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"	[illegible]	[illegible]	1.2071	0·999 9501	Sps 1.207
				[illegible]			0.6256209	1.2369		Spn 1.237
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"	"	0.6487104	1.1929	0·999 8005	Sps 1.193
				[illegible]			0.6177986	1.2526		Spn 1.252
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"	"	0.6563151	1.1791	0·999 5497	Sps 1.179
				[illegible]			0.6098762	1.2688		Spn 1.268
4 %	[illegible]	[illegible]	"	[illegible]	"	"	0.6638174	1.1657	0·999 2002	Sps 1.164
				[illegible]			[illegible]	1.2856		Spn 1.285
[illegible]	[illegible]	[illegible]	"	[illegible]	"	"	[illegible]	1.1529	0·998 7535	Sps 1.152
				[illegible]			[illegible]	1.3028		Spn 1.301



(Northern Slope

hours 12:00

SLOPE	Tang⁻¹	∠σ	∠β	∠α = ∠β ± ∠σ	∠φ	Sin φ	Sin α	S = H·Sin φ / Sin α	Cos σ	Sps or Spn
[illegible]	[illegible]	[illegible]	47° 00'	47° 00' 00"	[illegible]	[illegible]	0.7313537	0.9325	1·000 0000	Sp 0.932
[illegible]	0.01	0° 34' [illegible]	"	[illegible]	"	"	0.7381283	0.9240	0·999 9501	Sps 0.924
				[illegible]			0.7245061	0.9413		Spn 0.941
2 %	0.02	1° 8' [illegible]	"	[illegible]	"	"	0.7448294	0.9156	0·999 8005	Sps 0.915
				[illegible]			0.7175863	0.9504		Spn 0.950
3 %	0.03	1° 43' 6"	"	[illegible]	"	"	0.7514881	0.9075	0·999 5497	Sps 0.907
				[illegible]			0.7105607	0.9598		Spn 0.959
4 %	0.04	2° 17' 30"	"	[illegible]	"	"	0.7580395	0.8997	0·999 2002	Sps 0.899
				[illegible]			0.7033947	0.9696		Spn 1.969
5 %	0.05	2° 51' 40"	"	[illegible] 51 40	"	"	0.7644840	0.8921	0·998 7535	Sps 0.891
				44 8 20			0.6964001	0.9793		Spn 0.978

FORMULA

$\angle\alpha = \angle\beta \pm \angle\sigma$

$S = \frac{H \cdot \sin\phi}{\sin\alpha}$

Sps or Spn = $S \cdot \cos\sigma$

For Slopes h >5%

Sps or Spn = $\frac{100 \cdot S}{\sqrt{100^2 + h^2}}$

Date APRIL 21

hours 09:00&15:00

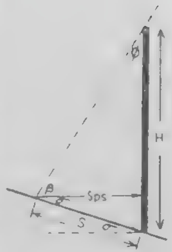
SLOPE h	Tang⁻¹	$\angle\sigma$	$\angle\beta$	$\angle\alpha = \angle\beta \pm \angle\sigma$	$\angle\Phi$	Sin Φ	Sin α	$S = \frac{H\cdot\sin\Phi}{\sin\alpha}$	Cos σ	Sps or Spn
0 %	0·00	0° 00' 00"	40° 6'	40° 6' 00"	49° 54'	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1 %	0·01	0° 34' 20"	"	[illegible]	"	[illegible]	[illegible]	[illegible]	0·999 9501	Sps [illegible]
				[illegible]			0.6364522	1.2018		Spn 1.201
2 %	0·02	1° 08' 40"	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0·999 8005	Sps [illegible]
				[illegible]			0.6287174	1.2166		Spn 1.216
3 %	0·03	1° 43' 10"	"	[illegible]	"	"	[illegible]	[illegible]	0·999 5497	Sps 1.147
				[illegible]			0.6208818	1.2320		Spn 1.231
4 %	0·04	2° 17' 30"	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0·999 2002	Sps [illegible]
				[illegible]			.6130220	[illegible]		Spn 1.247
5 %	0·05	2° 51' 40"	"	[illegible]	[illegible]	[illegible]	0.6815018	[illegible]	0·998 7535	Sps [illegible]
				[illegible] 14 [illegible]			[illegible]	[illegible]		Spn 1.262

hours 10:00 & 14:00

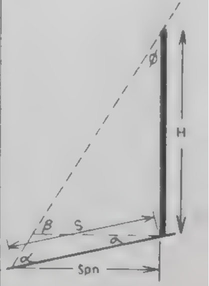
SLOPE h	Tang⁻¹	$\angle\sigma$	$\angle\beta$	$\angle\alpha = \angle\beta \pm \angle\sigma$	$\angle\Phi$	Sin Φ	Sin α	$S = \frac{H\cdot\sin\Phi}{\sin\alpha}$	Cos σ	Sps or Spn
0 %	0·00	0° 00' 00"	49° 27'	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Sp [illegible]
1 %	0·01	0° 34' 20"	"	[illegible]	[illegible]	[illegible]	.7662937	0.8484	0·999 9501	Sps 0.848
				48 [illegible] 4[illegible]			.7533084	0.8630		Spn 0.863
2 %	0·02	1° 08' 40"	"	[illegible] 3[illegible] 4[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0·999 8005	Sps 0.841
				4[illegible] 1[illegible] 2[illegible]			.7467027	[illegible]		Spn 0.870
3 %	0·03	1° 43' 10"	"	51 1[illegible] 1[illegible]	"	[illegible]	.7740037	[illegible]	0·999 5497	Sps 0.839
				47 43 [illegible]			.7399899	[illegible]		Spn 0.878
4 %	0·04	2° 17' 30"	"	[illegible] 44 3[illegible]	[illegible]	"	.7852269	[illegible]	0·999 2002	Sps 0.827
				4[illegible] [illegible] 3[illegible]			.7332356	[illegible]		Spn 0.887
5 %	0·05	2° 51' 40"	"	5[illegible] [illegible] 4[illegible]	[illegible]	"	[illegible]	[illegible]	[illegible]	Sps 0.820
				4[illegible] 3[illegible] [illegible]			[illegible]	[illegible]		Spn 0.894

hours 12:00

SLOPE h	Tang⁻¹	$\angle\sigma$	$\angle\beta$	$\angle\alpha = \angle\beta \pm \angle\sigma$	$\angle\Phi$	Sin Φ	Sin α	$S = \frac{H\cdot\sin\Phi}{\sin\alpha}$	Cos σ	Sps or Spn
0 %	0·00	0° 00' 00"	58° 36'	58° 36' 00"	31° 24'	[illegible]	.85[illegible]3	[illegible]	1·000 0000	Sp 0.610
1 %	0·01	0° 34' 20"	"	59 10 20	"	"	.85[illegible]7116	[illegible]	0·999 9501	Sps 0.607
				58 3 4[illegible]			0.8486218	0.6139		Spn 0.614
2 %	0·02	1° 08' 40"	"	59 44 40	"	"	0.8637867	0.6032	0·999 8005	Sps 0.603
				57 27 20			0.8429744	0.6181		Spn 0.618
3 %	0·03	1° 43' 10"	"	60 19 10	"	"	0.8687996	.5997	0·999 5497	Sps 0.599
				56 52 50			0.8375333	0.62207		Spn 0.621
4 %	0·04	2° 17' 30"	"	60 53 30	"	"	0.8737015	0.5963	0·999 2002	Sps 0.596
				56 18 30			0.8320348	0.62[illegible]		Spn 0.625
5 %	0·05	2° 51' 40"	"	61 27 40	"	"	0.8784930	0.5931	0·998 7535	Sps 0.592
				55 44 20			0.8264806	0.6304		Spn 0.630



(Southern Slope)



(Northern Slope)

FORMULA

$\angle\alpha = \angle\beta \pm \angle\sigma$

$S = \frac{H\cdot\sin\phi}{\sin\alpha}$

Sps or Spn = $S\cdot\cos\sigma$

For Slopes h >5%

Sps or Spn $\frac{100\cdot S}{\sqrt{100^2 + h^2}}$

Date MAY 21

hours 09:00 & 15:00

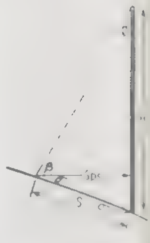
Slope h	Tang⁻¹	∠σ	∠β	∠α = ∠β ± ∠σ	∠φ	Sin φ	Sin α	S = H·Sin φ / Sin α	Cos σ	Sps or Spn
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1·000 0000	Sp 0.96[illegible]
1 %	[illegible]	[illegible] 34 [illegible]	"	[illegible] 20	"	"	0.7262415	0.9565	0·999 9501	Sps 0.956
				[illegible]			[illegible]4	0.9751		Spn 0.975
2 %	[illegible]	[illegible]	"	[illegible]	"	"	[illegible]	[illegible].9476	0·999 8005	Sps 0.947
				[illegible]			[illegible]	[illegible].984[illegible]		Spn 0.984
3 %	0·03	1° 43' 10"	"	47 43 10	"	"	0.7398595	[illegible]389	0·999 5497	Sps 0.939
				44 16 50			0.6981724	[illegible]		Spn 0.994
4 %	0·04	2° 17' 30"	"	48 17 30	"	"	0.7465414	[illegible]	0·999 2002	Sps 0.930
				43 42 30			0.6909876	1.[illegible]053		Spn 1.004
[illegible]	[illegible]	[illegible]	"	48 51 40	"	"	0.[illegible]	0.92[illegible]4	0·998 7535	Sps 0.921
				[illegible]			[illegible]	1.0159		Spn 1.015

hours 10:00 & 14:00

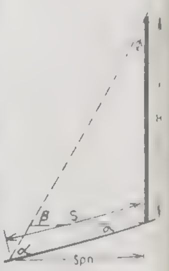
Slope h	Tang⁻¹	∠σ	∠β	∠α = ∠β ± ∠σ	∠φ	Sin φ	Sin α	S = H·Sin φ / Sin α	Cos σ	Sps or Spn
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.6770	1·000 0000	Sp 0.677
[illegible]	[illegible]	[illegible] 34 [illegible]	"	[illegible]	"	"	[illegible]	0.6725	0·999 9501	Sps 0.672
				[illegible]			[illegible]3224199	0.6817		Spn 0.682
[illegible]	[illegible]	[illegible]	"	[illegible]	"	"	[illegible]	0.6681	0·999 8005	Sps 0.668
				[illegible]			0.8166975	0.6864		Spn 0.686
3 %	[illegible]	[illegible] 43 [illegible]	"	[illegible]	"	"	0.8445097	0.6639	0·999 5497	Sps 0.664
				[illegible]			0.8108653	0.6914		Spn 0.691
[illegible]	[illegible]	[illegible]	"	[illegible]	"	"	0.8498160	0.6597	0·999 2002	Sps 0.659
				[illegible]			0.8049801	0.6964		Spn 0.696
[illegible]	[illegible]	[illegible] 5 [illegible] 40"	"	[illegible]	"	"	0.8440125	[illegible].6557	0·998 7535	Sps 0.655
				[illegible]			0.7990438	0.7016		Spn 0.701

hours 12:00

Slope h	Tang⁻¹	∠σ	∠β	∠α = ∠β ± ∠σ	∠φ	Sin φ	Sin α	S = H·Sin φ / Sin α	Cos σ	Sps or Spn
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible].4245	1·000 0000	Sp 0.424
1 %	[illegible]	[illegible] 34 [illegible]	"	[illegible]	"	[illegible]	[illegible]	0.4227	0·999 9501	Sps 0.423
				[illegible]			[illegible]	0.4263		Spn 0.426
[illegible]	[illegible]	[illegible] 08 4[illegible]	"	[illegible]	"	"	[illegible]	0.4210	0·999 8005	Sps 0.421
				[illegible]			[illegible]	[illegible].428[illegible]		Spn 0.428
3 %	[illegible]	[illegible] 43 [illegible]	"	[illegible]	"	[illegible]	[illegible]18149	[illegible].41[illegible]	0·999 5497	Sps 0.419
				[illegible]			[illegible]	[illegible].4301		Spn 0.430
4 %	0·04	2° 17' 30"	"	[illegible]	"	"	[illegible]	0.4177	0·999 2002	Sps 0.417
				[illegible]			0.9041447	0.4321		Spn 0.432
[illegible]	0·05	[illegible] 51' 40"	"	[illegible] 40	[illegible]	"	[illegible]	0.41676	0·998 7535	Sps 0.416
				[illegible]			[illegible]	[illegible].434[illegible]		Spn 0.434



(Southern [illegible]



(Northern Slope)

FORMULA

$\angle\alpha = \angle\beta \pm \angle\sigma$

$S = \dfrac{H \cdot \sin\phi}{\sin\alpha}$

Sps or Spn = S·COS σ

For Slopes h >5%

Sps or Spn [illegible]

Date JUNE 21

09:00&15:00 hours

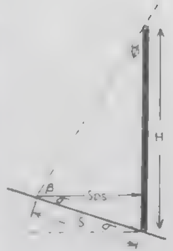
SLOPE	Tang $^{-1}$	∠a	∠β	∠α = ∠β ± ∠a	∠φ	Sin φ	Sin α	$S = \frac{H \cdot \sin\phi}{\sin\alpha}$	Cos a	Sps or Spn
0 %	0·00	0° 00' 00"	48° 12'	48°12' 00"	41° 48'	[illegible]	[illegible]	[illegible]	1·000 0000	Sp [illegible]
1 %	0·01	0° 34 20"	"	[illegible] [illegible]	"	[illegible]	[illegible] [illegible]	[illegible] [illegible]	0·999 9501	Sps [illegible] Spn 0.902
2 %	0·02	1° 08' 40"	"	[illegible] [illegible]	"	"	0.7586399 0.7320146	0.8786 0.9105	0·999 8005	Sps 0.87[illegible] Spn 0.910
3 %	0·03	1° 43' 10"	"	[illegible] [illegible]	"	"	[illegible] 0.7251073	[illegible] [illegible]	[illegible]	Sps [illegible] Spn [illegible]
4 %	0·04	2° 17' 30"	"	[illegible] 45 54 [illegible]	"	"	0.7715321 0.7182275	[illegible] [illegible]	0·999 2002	Sps [illegible] Spn [illegible]
5 %	0·05	2° 51' 40"	"	[illegible] [illegible]	"	"	[illegible] [illegible]	[illegible] [illegible]	0·998 7535	Sps [illegible] Spn [illegible]

10:00&14:00 hours

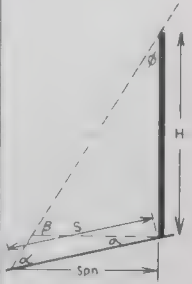
SLOPE	Tang $^{-1}$	∠a	∠β	∠α = ∠β ± ∠a	∠φ	Sin φ	Sin α	$S = \frac{H \cdot \sin\phi}{\sin\alpha}$	Cos a	Sps or Spn
0 %	0·00	0° 00' 00"	58° 30'	58° 30' 00"	31° 30'	0.5224[illegible]	[illegible]	[illegible]	1·000 0000	Sp [illegible]
1 %	0·01	0° 34' 20"	"	59 4 [illegible] 57 [illegible] 40	"	"	[illegible] [illegible]	[illegible] [illegible]	[illegible]	Sps [illegible] Spn [illegible]
2 %	0·02	1° 08' 40"	"	59 38 40 5[illegible] 21 2[illegible]	"	"	0.8629059 [illegible]	0.60[illegible] [illegible]	[illegible]	Sps [illegible] Spn [illegible]
3 %	0·03	1° 43' 10"	"	60 13 10 5[illegible] 46 [illegible]	"	"	[illegible] [illegible]	[illegible] [illegible]	0·999 5497	Sps [illegible] Spn [illegible]
4 %	0·04	2° 17' 30"	"	60 47 30 56 12 30	"	"	[illegible] [illegible]	[illegible] [illegible]	0·999 2002	Sps [illegible] Spn [illegible]
5 %	0·05	2° 51' 40"	"	61 21 4[illegible] 55 38 20	"	"	[illegible] [illegible]	[illegible] [illegible]	0·998 7535	Sps [illegible] Spn [illegible]

12:00 hours

SLOPE	Tang $^{-1}$	∠a	∠β	∠α = ∠β ± ∠a	∠φ	Sin φ	Sin α	$S = \frac{H \cdot \sin\phi}{\sin\alpha}$	Cos a	Sps or Spn
0 %	0·00	0° 00' 00"	70° 24'	70° 24' 00"	19° 36'	0.3354[illegible]	[illegible]	[illegible]	[illegible]	Sp [illegible].356
1 %	0·01	0° 34' 20"	"	70 58 20 69 49 40	"	"	[illegible] [illegible]	[illegible] [illegible]	[illegible]	Sps [illegible] Spn [illegible]
2 %	0·02	1° 08' 40'	"	71 32 40 69 15 2[illegible]	"	"	[illegible] [illegible]	[illegible] [illegible]	[illegible]	Sps [illegible] Spn [illegible].358
3 %	0·03	1° 43' 10"	"	72 7 10 68 40 5[illegible]	"	"	0.9516987 0.9315679	0.3525 0.36[illegible]1	0·999 5497	Sps 0.352 Spn 0.360
4 %	0·04	2° 17' 30"	"	72 41 30 68 6 30	"	"	0.954717[illegible] 0.9278905	0.3514 0.3615	[illegible]	Sps [illegible] Spn [illegible].361
5 %	0·05	2° 51' 40"	"	73 15 40 6[illegible] 32 2[illegible]	"	"	0.9576272 0.9241391	0.350[illegible] 0.3630	0·998 7535	Sps 0.350 Spn 0.363



(Southern Slope)



(Northern Slope)

FORMULA

$\angle\alpha = \angle\beta \pm \angle a$

$S = \frac{H \cdot \sin\phi}{\sin\alpha}$

Sps or Spn = S·COS a

For Slopes h > 5%

$\text{Sps or Spn} = \frac{100 \cdot S}{\sqrt{100^2 + h^2}}$

Date JULY 21

hours 09:00 & 15:00

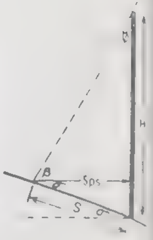
SLOPE	Tang⁻¹	∠σ	∠β	∠α = ∠β ± ∠σ	∠φ	Sin φ	Sin α	S = H·Sin φ / Sin α	Cos σ	Sps or Spn
0 %	0.00	0° 00' 00"	[illegible] 24'	46° 24' 00"	[illegible]	[illegible]	0.7241719	0.9522	1·000 0000	Sp 0.952
1 %	0.01	0° 34' 20"	"	46 58 20	"	"	0.7310230	0.9437	0·999 9501	Sps 0.944
				45 49 40			0.7172485	0.9615		Spn 0.961
2 %	0.02	1° 08' 40"	"	47 32 40	"	"	[illegible]	0.9347	0·999 8005	Sps 0.935
				[illegible]			[illegible]	0.9709		Spn 0.971
3 %	0.03	1° 43' 10"	"	[illegible]	"	"	[illegible]581	0.9262	0·999 5497	Sps 0.926
				44 [illegible]			[illegible]534	0.9807		Spn 0.980
4 %	0.04	2° 17' 30"	"	[illegible]	"	"	0.7511681	0.9181	0·999 2002	Sps 0.917
				[illegible]			0.6960172	0.9908		Spn 0.990
5 %	0.05	2° 51' 40"	"	[illegible]	"	"	0.7576916	0.9102	0·998 7535	Sps 0.909
				[illegible]			0.6888468	1.0011		Spn 0.999

hours 10:00 & 14:00

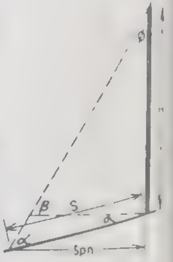
SLOPE	Tang⁻¹	∠σ	∠β	∠α = ∠β ± ∠σ	∠φ	Sin φ	Sin α	S = H·Sin φ / Sin α	Cos σ	Sps or Spn
0 %	0.00	0° 00' 00"	[illegible] 24'	[illegible]	[illegible]	[illegible]	[illegible]9113	0.6644	1·000 0000	Sp 0.664
1 %	0.01	0° 34' 20"	"	[illegible]	"	"	[illegible]	0.6632	0·999 9501	Sps 0.663
				[illegible]			[illegible]	0.6689		Spn 0.669
2 %	0.02	1° 08' 40"	"	[illegible]	"	"	[illegible]	0.6558	0·999 8005	Sps 0.656
				[illegible]			0.8217022	0.6735		Spn 0.673
3 %	0.03	1° 43' 10"	"	58 7 10	"	"	0.8491510	0.6517	0·999 5497	Sps 0.651
				54 40 50			[illegible]9414	0.6782		Spn 0.677
4 %	0.04	2° 17' 30"	"	58 41 30	"	"	0.8543833	0.6477	0·999 2002	Sps 0.647
				54 6 30			[illegible]	0.6831		Spn 0.682
5 %	0.05	2° 51' 40"	"	59 15 40	"	"	0.8595055	0.6438	0·998 7535	Sps 0.643
				[illegible]			[illegible]	0.6881		Spn 0.687

hours 12:00

SLOPE	Tang⁻¹	∠σ	∠β	∠α = ∠β ± ∠σ	∠φ	Sin φ	Sin α	S = H·Sin φ / Sin α	Cos σ	Sps or Spn
0 %	0.00	0° 00' 00"	[illegible]	[illegible]	[illegible] 11'	[illegible]4	0.9245460	0.4122	1·000 0000	Sp 0.412
1 %	0.01	0° 34' 20"	"	[illegible]	"	"	[illegible]	0.4105	0·999 9501	Sps 0.410
				67 1 40			0.9206942	0.4139		Spn 0.414
2 %	0.02	1° 08' 40"	"	68 44 40	"	"	0.9319727	0.4089	0·999 8005	Sps 0.409
				66 27 20			[illegible]	0.415[illegible]		Spn 0.416
3 %	0.03	1° 43' 10"	"	69 19 10	"	"	[illegible]	0.4073	0·999 5497	Sps 0.407
				[illegible]			[illegible]	0.4175		Spn 0.417
4 %	0.04	2° 17' 30"	"	[illegible] 10	"	"	0.9390443	0.4058	0·999 2002	Sps 0.405
				[illegible]			[illegible]	0.4194		Spn 0.419
5 %	0.05	2° 51' 40"	"	[illegible]	"	"	[illegible]4147	0.4043	0·998 7535	Sps 0.404
				64 44 20			[illegible]	0.4214		Spn 0.421



(Southern Slope



(Northern Slope)

FORMULA

∠α = ∠β ± ∠σ

$S = \frac{H \cdot \sin\phi}{\sin\alpha}$

Sps or Spn = S·COS σ

For Slopes h >5%

$\text{Sps or Spn} = \frac{100 \cdot S}{\sqrt{100^2 + h^2}}$

Date AUGUST 21

hours 09:00&15:00

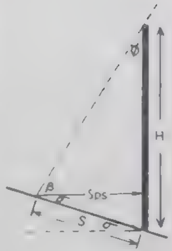
SLOPE	Tang⁻¹	∠σ	∠β	∠α = ∠β ± ∠σ	∠φ	Sin φ	Sin α	$S=\frac{H\cdot\sin\phi}{\sin\alpha}$	Cos σ	Sps or Spn
0 %	0·00	0° 00 [illegible]	[illegible]	[illegible]	[illegible]	0.7592713	0.6507742	1.1667	1·000 0000	Sp [illegible]
[illegible] %	0·01	0° 34 20"	"	[illegible] [illegible]	[illegible]	"	0.6583246 [illegible]	1.1533 [illegible]	0·999 9501	Sps [illegible] Spn [illegible]
2 %	0·02	1° 08' 40"	"	[illegible] [illegible]	"	[illegible]	[illegible] .6354795	[illegible] 1.1948	0·999 8005	Sps 1.140 Spn 1.194
3 %	0·03	1° 43' 10"	"	[illegible] [illegible]	[illegible]	"	0.6732635 0.6276989	1.1277 [illegible]	0·999 5497	Sps 1.127 Spn [illegible]
4 %	0·04	2° 17' 30"	"	[illegible] 38 18 [illegible]	"	[illegible]	[illegible] [illegible]	[illegible] [illegible]	0·999 2002	Sps [illegible] Spn [illegible]
5 %	0·05	2° 51' 40"	"	43 27 4[illegible] [illegible] 44 [illegible]	"	[illegible]	[illegible] [illegible]	[illegible] [illegible]	0·998 7535	Sps [illegible] Spn [illegible]

hours 10:00 & 14 00

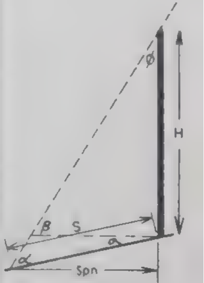
SLOPE	Tang⁻¹	∠σ	∠β	∠α = ∠β ± ∠σ	∠φ	Sin φ	Sin α	$S=\frac{H\cdot\sin\phi}{\sin\alpha}$	Cos σ	Sps or Spn
0 %	0·00	0° 00' 00"	49°48'	49° 48' [illegible]"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Sp 0.845
1 %	0·01	0° 34' 20"	"	[illegible] [illegible] 13 [illegible]	[illegible]	[illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible]	Sps [illegible] Spn [illegible]
2 %	0·02	1° 08' 40"	"	[illegible] 56 [illegible] 48 39 [illegible]	"	"	[illegible] [illegible]	[illegible] [illegible]	[illegible]	Sps [illegible] Spn [illegible]
3 %	0·03	1° 43' 10"	"	51 31 10 48 4 50	"	"	[illegible] [illegible]	[illegible] [illegible]	[illegible]	Sps [illegible] Spn [illegible]
4 %	0·04	2° 17' 30"	"	[illegible] [illegible]	"	"	[illegible] [illegible]	[illegible] [illegible]	[illegible]	Sps [illegible] Spn [illegible]
5 %	0·05	2° 51' 40"	"	[illegible] 39 40 46 56 20	"	[illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible]	Sps [illegible] Spn [illegible]

hours 1200

SLOPE	Tang⁻¹	∠σ	∠β	∠α = ∠β ± ∠σ	∠φ	Sin φ	Sin α	$S=\frac{H\cdot\sin\phi}{\sin\alpha}$	Cos σ	Sps or Spn
[illegible] %	0·00	0° 00' 00"	59°18'	59°18'00"	[illegible]°42'	[illegible]	[illegible].8498523	[illegible]	[illegible]000 0000	Sp [illegible].593
[illegible] %	0·01	0° 34' 20"	"	59 52 20 58 43 40	"	"	[illegible] [illegible]	[illegible] [illegible]	0·999 9501	Sps 0.590 Spn [illegible].597
[illegible] %	0·02	1° 08' 40"	"	60 26 40 58 9 20	"	"	[illegible] [illegible]	[illegible] [illegible]	[illegible]	Sps [illegible] Spn [illegible]
3 %	0·03	1° 43' 10"	"	61 1 10 57 34 50	"	[illegible]	0.8747842 [illegible]	0.5836 0.6048	[illegible]	Sps 0.583 Spn [illegible]
4 %	0·04	2° 17' 30"	"	61 35 30 57 0 30	"	"	0.8795794 0.8387498	0.5804 0.6087	[illegible]	Sps [illegible].580 Spn [illegible].608
[illegible] %	0·05	2° 51' 40"	"	62 9 40 56 6 20	"	"	[illegible] [illegible].8332967	[illegible] [illegible]	0·998 7535	Sps 0.608 Spn [illegible]



(Southern Slope)



(Northern Slope)

FORMULA

$\angle\alpha = \angle\beta \pm \angle\sigma$

$S = \frac{H\cdot\sin\phi}{\sin\alpha}$

Sps or Spn = S·COS σ

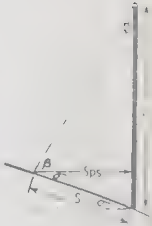
For Slopes h >5%

$\text{Sps or Spn} = \frac{100\cdot S}{\sqrt{100^2 + h^2}}$

Date SEPTEMBER 21

hours 09:00&15:00

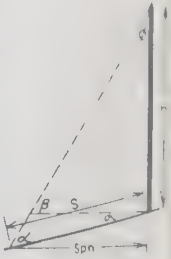
Slope	Tang $^{-1}$	∠σ	∠β	∠α = ∠β ± ∠σ	∠φ	Sin φ	Sin α	$S=\frac{H\cdot\sin\phi}{\sin\alpha}$	Cos σ	Sps or Spn
0 %	[illegible]	[illegible]	31°06'	31°06' 00"	[illegible]	[illegible]	.5165333	1.6577	1000 0000	Sp 1.657
1 %	[illegible]	[illegible]	"	31 40 20	"	"	[illegible]	1.6308	0·999 9501	Sps 1.631
				[illegible]			.5079560	1.6857		Spn 1.686
2 %	[illegible]	[illegible]	"	32 14 40	"	"	.5335325	1.6049	0·999 8005	Sps 1.605
				[illegible]			.4993281	1.7148		Spn 1.714
3 %	[illegible]	[illegible]	"	[illegible]	"	"	[illegible]	1.5799	0·999 5497	Sps 1.579
				[illegible]			[illegible]	1.7453		Spn 1.745
4 %	[illegible]	[illegible]	"	[illegible]	"	"	.5503593	1.5558	0·999 2002	Sps 1.555
				[illegible]			.4814811	1.7769		Spn 1.776
5 %	[illegible]	[illegible]	"	[illegible]	"	"	.5586301	1.5328	0·998 7535	Sps 1.531
				[illegible]			.4731488	1.8097		Spn 1.807



(Southern Slope

hours 10:00 & 14:00

Slope	Tang $^{-1}$	∠σ	∠β	∠α = ∠β ± ∠σ	∠φ	Sin φ	Sin α	$S=\frac{H\cdot\sin\phi}{\sin\alpha}$	Cos σ	Sps or Spn
[illegible]	[illegible]	0° 00' 00"	39°[illegible]'	39°[illegible]' 00"	50°4[illegible]'	0.7738[illegible]	0.6333809	1.2218	1·000 0000	Sp 1.221
[illegible]	[illegible]	0° 34' 20"	"	39 52 20	"	"	0.6410776	1.2071	0·999 9501	Sps 1.207
				38 4[illegible] 40			0.6256209	1.2369		Spn 1.236
[illegible]	[illegible]	[illegible]	"	[illegible]	"	"	.6487104	1.1929	0·999 8005	Sps 1.193
				[illegible]			[illegible]	1.2526		Spn 1.252
[illegible]	[illegible]	1° 43' 10"	"	[illegible]	"	"	[illegible]	1.1791	0·999 5497	Sps 1.179
				[illegible]			[illegible]	1.2689		Spn 1.268
[illegible]	[illegible]	[illegible]	"	[illegible]	"	"	[illegible]	1.1657	0·999 2002	Sps 1.165
				[illegible]			[illegible]	1.2856		Spn 1.285
5 %	0.05	2° 5[illegible]' 40"	"	[illegible]	"	"	[illegible]	1.1529	0·998 7535	Sps 1.152
				[illegible]			[illegible]	1.3028		Spn 1.301



(Northern Slope

hours 12:00

Slope	Tang $^{-1}$	∠σ	∠β	∠α = ∠β ± ∠σ	∠φ	Sin φ	Sin α	$S=\frac{H\cdot\sin\phi}{\sin\alpha}$	Cos σ	Sps or Spn
0 %	[illegible]	0° 00' 00"	47°00'	47°00' 00"	43° 00'	0.6819984	0.7313537	0.9325	1·000 0000	Sp 0.932
1 %	0.01	0° 34 20	"	47 34 20	"	"	0.7381283	0.9240	0·999 9501	Sps 0.924
				46 25 40			0.7245061	0.9413		Spn 0.941
2 %	0.02	1° 08 40	"	48 8 40	"	"	0.7448294	0.9156	0·999 8005	Sps 0.915
				45 51 20			0.7172863	0.9504		Spn 0.950
3 %	0.03	1° 43 10"	"	48 43 10	"	"	0.7514881	0.9075	0·999 5497	Sps 0.907
				45 16 50			0.7105607	0.9598		Spn 0.959
4 %	0.04	2° 17' 30	"	49 17 30	"	"	0.7581395	0.8997	0·999 2002	Sps 0.899
				44 42 30			0.7034981	0.9694		Spn 0.969
5 %	0.05	2° 51 40"	"	49 51 40	"	"	0.7644840	0.8921	0·998 7535	Sps 0.891
				44 8 20			0.6964001	0.9793		Spn 0.978

FORMULA

∠α = ∠β ± ∠σ

$S = \frac{H\cdot\sin\phi}{\sin\alpha}$

Sps. or Spn = S·COS σ

For Slopes h >5%

Sps or Spn = $\frac{100\cdot S}{\sqrt{100^2 + h^2}}$

Date OCTOBER 21

09:00&15:00 hours

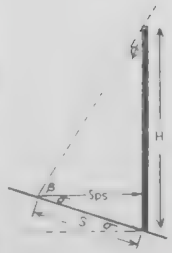
SLOPE	Tang⁻¹	∠σ	∠β	∠α = ∠β ± ∠σ	∠φ	Sin φ	Sin α	S = H·Sin φ / Sin α	Cos σ	Sps or Spn
0 %	0·00	0° 00' 00"	22° 36'	[illegible]	[illegible]	[illegible]	0.3842953	[illegible]	[illegible]	Sp [illegible]
1 %	0·01	0° 34' 20"	"	[illegible]	"		0.3934963	[illegible]	0·999 9501	Sps [illegible]
				[illegible]			[illegible]	[illegible]		Spn [illegible]
2 %	0·02	1° 08' 40"	"	23 44 40	"	"	0.4026579	[illegible]	0·999 8005	Sps [illegible]
				[illegible]			0.3657794	[illegible]		Spn [illegible]
3 %	0·03	1° 43' 10"	"	24 19 [illegible]	"	"	[illegible]	[illegible]	0·999 5497	Sps [illegible]
				[illegible]			[illegible]	[illegible]		Spn [illegible]
4 %	0·04	2° 17' 30"	"	[illegible]	"	"	[illegible]	[illegible]	0·999 2002	Sps [illegible]
				[illegible]			[illegible]	[illegible]		Spn [illegible]
5 %	0·05	2° 51' 40"	"	25 [illegible]	[illegible]	"	[illegible]	[illegible]	0·998 7535	Sps [illegible]
				19 44 [illegible]			[illegible]	[illegible]		Spn [illegible]

10:00 & 14:00 hours

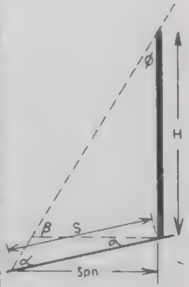
SLOPE	Tang⁻¹	∠σ	∠β	∠α = ∠β ± ∠σ	∠φ	Sin φ	Sin α	S = H·Sin φ / Sin α	Cos σ	Sps or Spn
0 %	0·00	0° 00' 00"	29°54'	29°54' 00"	60°06'	0.8668967	0.4984877	[illegible]	[illegible]	Sp [illegible]
1 %	0·01	0° 34' 20"	"	30 28 20	"	"	0.5071206	[illegible]	0·999 9501	Sps [illegible]
				29 19 40			0.4898052	1.7699		Spn [illegible]
2 %	0·02	1° 08' 40"	"	31 2 4[illegible]	"	"	0.5157028	1.6810	0·999 8005	Sps [illegible]
				28 45 20			0.4810738	1.8020		Spn [illegible]
3 %	0·03	1° 43' 10"	"	31 37 10	"	"	0.5242749	1.6535	0·999 5497	Sps [illegible]
				28 10 50			0.4722517	1.8357		Spn [illegible]
4 %	0·04	2° 17' 30"	"	32 1 30	"	"	0.5302892	1.6348	0·999 2002	Sps [illegible]
				27 36 30			0.4634249	1.8706		Spn [illegible]
5 %	0·05	2° 51' 40"	"	32 45 40	"	"	0.5411376	1.6020	0·998 7535	Sps [illegible]
				27 2 20			0.4545952	1.9060		Spn [illegible]

12:00 hours

SLOPE	Tang⁻¹	∠σ	∠β	∠α = ∠β ± ∠σ	∠φ	Sin φ	Sin α	S = H·Sin φ / Sin α	Cos σ	Sps or Spn
0 %	0·00	0° 00' 00"	36°30'	36°30'00"	53°30'	0.80385[illegible]9	0.5948228	1.[illegible]514	1·000 0000	Sp 1.351
1 %	0·01	0° 34' 20"	"	37 3 20	"	"	0.6028212	1.[illegible]514	0·999 9501	Sps 1.35[illegible]
				35 55 40			0.58[illegible]	1.3[illegible]0		Spn 1.370
2 %	0·02	1° 08' 40"	"	37 38 40	"	"	0.61[illegible]596	1.316[illegible]	0·999 8005	Sps 1.3[illegible]5
				35 21 [illegible]			0.578646[illegible]	1.389[illegible]		Spn 1.389
3 %	0·03	1° 43' 10"	"	3[illegible] 13 10	"	"	0.618[illegible]	[illegible]	0·999 5497	Sps 1.238
				34 46 50			0.57[illegible]	[illegible]		Spn 1.409
4 %	0·04	2° 17' 30"	"	38 47 30	"	"	0.62649[illegible]	1.2831	0·999 2002	Sps 1.28[illegible]
				34 12 30			0.5622037	1.4265		Spn 1.4[illegible]
5 %	0·05	2° 51' 40"	"	39 21 40	"	"	0.6342059	1.2675	0·998 7535	Sps 1.[illegible]
				33 38 20			0.5539568	1.4511		Spn 1.449



(Southern Slope)



(Northern Slope)

FORMULA

$\angle\alpha = \angle\beta \pm \angle\sigma$

$S = \frac{H \cdot \sin \phi}{\sin \alpha}$

Sps or Spn $S \cdot \cos \sigma$

For Slopes h >5%

Sps or Spn $= \frac{100 \cdot S}{\sqrt{100^2 + h^2}}$

Date NOVEMBER 21

09:00 & 15:00 hours

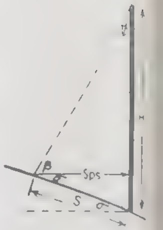
SLOPE h	Tang $^{-1}$	$\angle\sigma$	$\angle\beta$	$\angle\alpha = \angle\beta \pm \angle\sigma$	$\angle\phi$	Sin ϕ	Sin α	$S = \frac{H \cdot \sin\phi}{\sin\alpha}$	Cos σ	Sps or Spn
0 %	0·00	0° 00' 00"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.7846	1·000 0000	Sp 3.784
1 %	0·01	0° 34' 20"	"	[illegible]	"	"	[illegible]	3.6472	0·999 9501	Sps 3.647
				[illegible]			[illegible]	3.9337		Spn 3.934
2 %	0·02	1° 08' 40"	"	[illegible]	"	"	[illegible]	3.5195	0·999 8005	Sps 3.519
				[illegible]			[illegible]	4.0952		Spn 4.094
3 %	0·03	1° 43' 10"	"	[illegible]	"	"	[illegible]	3.4002	0·999 5497	Sps 3.399
				[illegible]			[illegible]	4.2719		Spn 4.270
4 %	0·04	2° 17' 30"	"	[illegible]	"	"	[illegible]	3.2896	0·999 2002	Sps 3.287
				[illegible]			[illegible]	4.6025		Spn 4.599
5 %	0·05	2° 51' 40"	"	17 39 40	"	"	0.3033864	3.1868	0·998 7535	Sps 3.183
				[illegible]			[illegible]	4.6736		Spn 4.668

10:00 & 14:00 hours

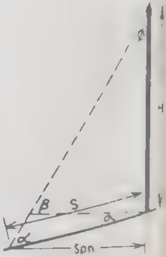
SLOPE h	Tang $^{-1}$	$\angle\sigma$	$\angle\beta$	$\angle\alpha = \angle\beta \pm \angle\sigma$	$\angle\phi$	Sin ϕ	Sin α	$S = \frac{H \cdot \sin\phi}{\sin\alpha}$	Cos σ	Sps or Spn
0 %	0·00	0° 00' 00"	21° 24'	21° 24' 00"	[illegible]	[illegible]	0.3648768	2.5515	1·000 0000	Sp 2.551
1 %	0·01	0° 34' 20"	"	21 58 20	"	"	0.3741570	2.4883	0·999 9501	Sps 2.488
				20 49 40			0.3555601	2.6186		Spn 2.619
2 %	0·02	1° 08' 40"	"	22 32 40	"	"	0.3834000	2.4284	0·999 8005	Sps 2.428
				[illegible]			[illegible]	2.6893		Spn 2.688
3 %	0·03	1° 43' 10"	"	23 7 10	"	"	[illegible]	2.3712	0·999 5497	Sps 2.370
				19 40 50			0.3367757	2.7646		Spn 2.763
4 %	0·04	2° 17' 30"	"	[illegible]	"	"	[illegible]	2.3171	0·999 2002	Sps 2.315
				[illegible]			[illegible]	2.8442		Spn 2.842
5 %	0·05	2° 51' 40"	"	24 16 40	"	"	0.4111608	2.2644	0·998 7535	Sps 2.262
				[illegible]			[illegible]	2.9283		Spn 2.925

12:00 hours

SLOPE h	Tang $^{-1}$	$\angle\sigma$	$\angle\beta$	$\angle\alpha = \angle\beta \pm \angle\sigma$	$\angle\phi$	Sin ϕ	Sin α	$S = \frac{H \cdot \sin\phi}{\sin\alpha}$	Cos σ	Sps or Spn
0 %	0·00	0° 00' 00"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1·000 0000	Sp 1.945
1 %	0·01	0° 34' 20"	"	[illegible]	"	"	0.4659577	1.9088	0·999 9501	Sps 1.909
				26 37 40			[illegible]	1.9844		Spn 1.984
2 %	0·02	1° 08' 40"	"	[illegible]	"	"	[illegible]	1.8733	0·999 8005	Sps 1.873
				[illegible]			[illegible]	[illegible]		Spn 2.024
3 %	0·03	1° 43' 10"	"	[illegible]	"	"	0.4835795	1.8392	0·999 5497	Sps 1.838
				[illegible]			0.4302408	2.0673		Spn 2.066
4 %	0·04	2° 17' 30"	"	[illegible]	"	"	0.4922970	1.8067	0·999 2002	Sps 1.805
				[illegible]			[illegible]	[illegible]		Spn 2.110
5 %	0·05	2° 51' 40"	"	[illegible]	"	"	[illegible]	1.7756	0·998 7535	Sps 1.773
				[illegible]			[illegible]	2.1581		Spn 2.156



(Southern



(Northern Slope)

FORMULA

$\angle\alpha = \angle\beta \pm \angle\sigma$

$S = \frac{H \cdot \sin\phi}{\sin\alpha}$

Sps or Spn = $S \cdot \cos\sigma$

For Slopes h >5%

Sps or Spn = $\frac{100 \cdot S}{\sqrt{100^2 + h^2}}$

Date DECEMBER 21

hours 09:00&15:00

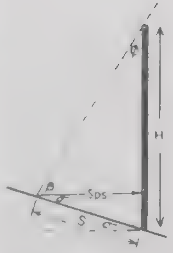
Slope	Tang⁻¹	∠σ	∠β	∠α = ∠β ± ∠σ	∠φ	Sin φ	Sin α	S = H·Sin φ / Sin α	Cos σ	Sps or Spn
0 %	0·00	0° 00 [illegible]	[illegible]	[illegible]	[illegible]	0.9 9228	0.2027873	4.8288	1·000 0000	Sp 4.828
%	0·01	0° 34 20"	"	[illegible] 11 15 40	"	"	0.2125567 0.1952805	[illegible] 5.0144	0·999 9501	Sps [illegible] Spn [illegible]
2 %	0·02	1° 08 40"	"	12 50 40 10 33 20	"	"	0.2223049 0.1831888	[illegible] [illegible]	0·999 8005	Sps [illegible] Spn [illegible]
3 %	0·03	1° 43 10	"	[illegible] [illegible]	[illegible]	[illegible]	[illegible] [illegible]733140	[illegible] 5.6500	0·999 5497	Sps [illegible] Spn [illegible]
4 %	0·04	2° 17 30'	"	[illegible] [illegible]	[illegible]	[illegible]	[illegible] [illegible]	[illegible] [illegible]	0·999 2002	Sps [illegible] Spn [illegible]
5 %	0·05	2° 51' 40"	"	[illegible] [illegible]	[illegible]	[illegible]	[illegible] [illegible]	[illegible] [illegible]	0·998 7535	Sps [illegible] Spn [illegible]

hours 10:00 & 14:00

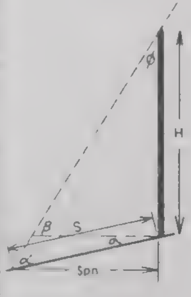
Slope	Tang⁻¹	∠σ	∠β	∠α = ∠β ± ∠σ	∠φ	Sin φ	Sin α	S = H·Sin φ / Sin α	Cos σ	Sps or Spn
0 %	0·00	0° 00' 00"	18° 00'	18° [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Sp [illegible]
1 %	0·01	0° 34' 20"	"	18 34 20 [illegible]	"	"	0.3184998 [illegible]	2.9866 [illegible]	[illegible]	Sps 2.986 Spn [illegible]
2 %	0·02	1° 08' 40"	"	19 8 40 [illegible]	"	"	0.3279508 [illegible]	2.9005 [illegible]	[illegible]	Sps [illegible] Spn 3.[illegible]
3 %	0·03	1° 43' 10"	"	19 43 10 16 16 50	"	"	0.3374147 [illegible]	2.8192 [illegible]	[illegible]	Sps [illegible] Spn [illegible]
4 %	0·04	2° 17' 30"	"	20 17 30 [illegible]	"	"	[illegible] [illegible]	[illegible] [illegible]	[illegible]	Sps [illegible] Spn [illegible]
5 %	0·05	2° 51' 40"	"	20 51 40 [illegible]	"	"	[illegible] [illegible]	[illegible] [illegible]	[illegible]	Sps [illegible] Spn 3.6[illegible]8

hours 12:00

Slope	Tang⁻¹	∠σ	∠β	∠α = ∠β ± ∠σ	∠φ	Sin φ	Sin α	S = H·Sin φ / Sin α	Cos σ	Sps or Spn
0 %	0·00	0° 00' 00'	23° 36'	[illegible] 36' [illegible]"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Sp [illegible]
%	0·01	0° 34' 20'	"	[illegible] 23 1 40	"	"	[illegible] 0.3911774	[illegible] 2.[illegible]	·999 9501	Sps [illegible] Spn 2.34[illegible]
[illegible] %	0·02	1° 08' 40"	"	[illegible] 44 4[illegible] [illegible]	"	"	[illegible] [illegible]	[illegible] [illegible]	[illegible]	Sps 2.[illegible]69 Spn 2.[illegible]98
3 %	0·03	1° 43' 10"	"	[illegible] [illegible] 52 50	"	"	[illegible] [illegible]	[illegible] 2.45[illegible]	0·999 5497	Sps 2.142 Spn 2.458
4 %	0·04	2° 17' 30"	"	[illegible] 53 30 21 18 30	"	"	[illegible] [illegible]	[illegible] [illegible]	[illegible]	Sps 2.[illegible]7 Spn 2.52[illegible]
5 %	0·05	2° 51' 40"	"	[illegible] 40 20 44 20	"	"	[illegible] [illegible]	[illegible] 2.58[illegible]	0·998 7535	Sps 2.[illegible]4 Spn 2.[illegible]84



(Southern Slope)



(Northern Slope)

FORMULA

$\angle\alpha = \angle\beta \pm \angle\sigma$

$S = \frac{H \cdot \sin\phi}{\sin\alpha}$

Sps or Spn = $S \cdot \cos\sigma$

For Slopes h > 5%

Sps or Spn = $\frac{100 \cdot S}{\sqrt{100^2 + h^2}}$

WIND SPEED AND DIRECTION HOURLY
- RECORDED FROM JANUARY, 1976 TO DECEMBER, 1979

THE WIND SPEED WAS RECORDED IN EIGHT DIRECTIONS UP TO YEAR 1975. SINCE 1976, RECORDINGS WERE EXTENDED TO SIXTEEN DIRECTIONS.

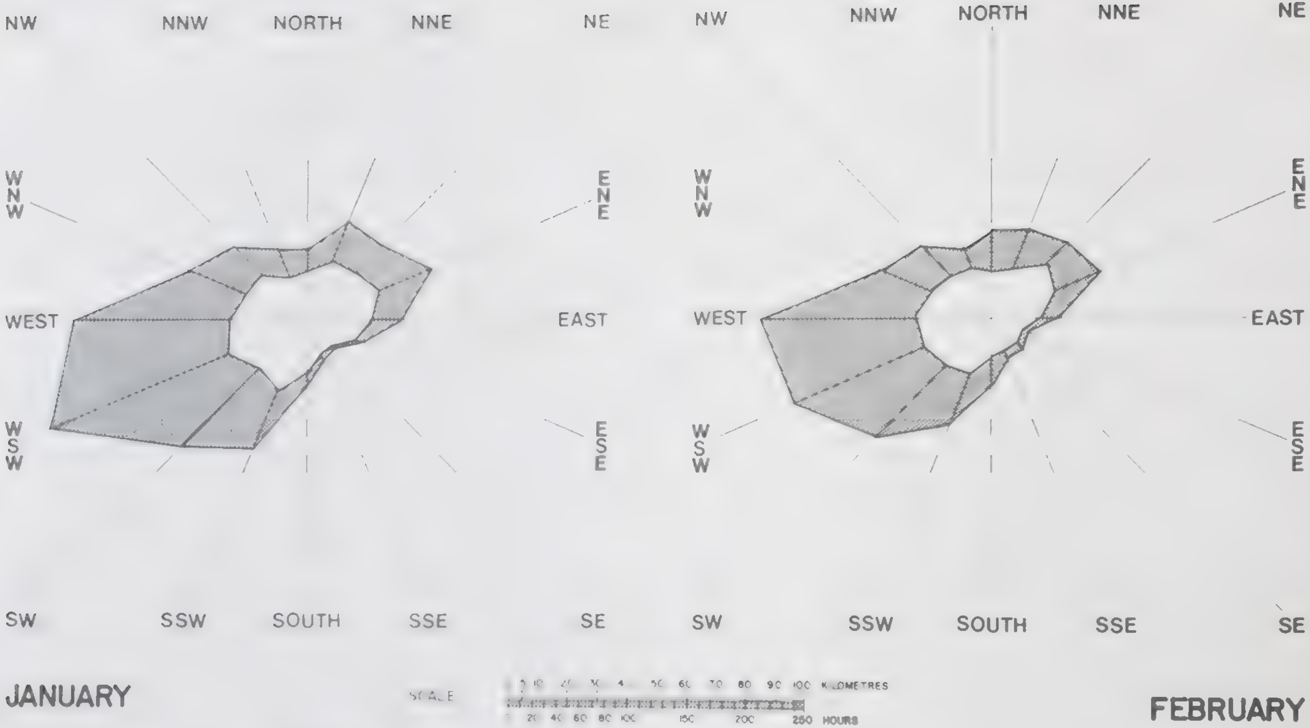
APPENDIX C

WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION

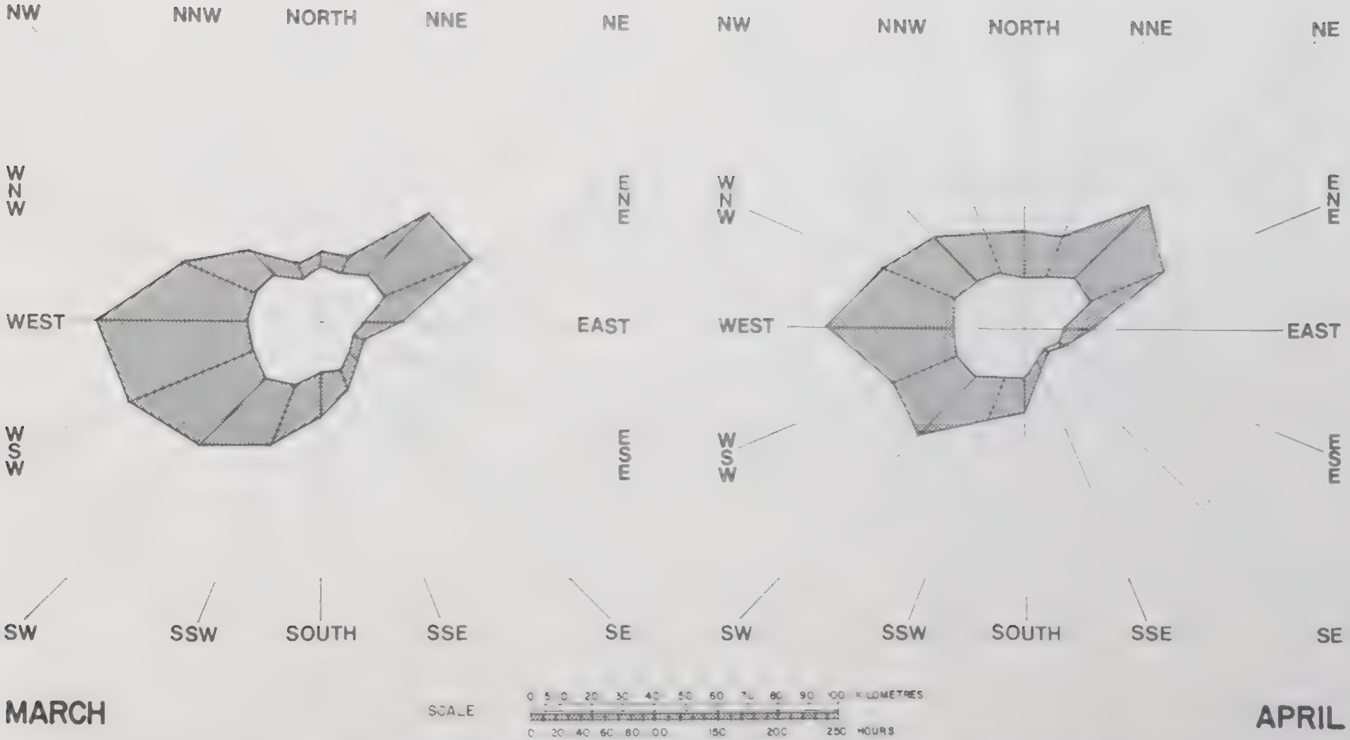
		NORTH		NNE		NE		ENE		EAST		ESE		SE		SSE		SOUTH		SSW		SW		WSW		WEST		WNW		NW		NNW	
		SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS
	1976	15	14	[illegible]	[illegible]	[illegible]																											
	1977																																
	1978																												4				
	1979																																
	TOTAL																																
	AVERAGE SPEED HOURS																																
FEBRUARY	1976																								[illegible]	30	98	23	48	26	54	17	
	1977																							[illegible]	[illegible]	24	183	19		[illegible]			
	1978	[illegible]																								[illegible]	162	[illegible]	[illegible]	11	[illegible]	[illegible]	
	1979																										80	26					
	TOTAL																								[illegible]	99	523	82	184	76	[illegible]		
	AVERAGE SPEED HOURS																								[illegible]	25	131	21	46	19			
	1976																									31	103	24	81	20			
	1977																								[illegible]	[illegible]	89				[illegible]		
	1978																								[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
	1979																												[illegible]		[illegible]	1	
	TOTAL																										[illegible]	[illegible]	[illegible]		11		
	AVERAGE SPEED HOURS																																
	1976																																
	1977																																
	1978																																
	1979																								44	[illegible]	11		[illegible]		[illegible]		
	TOTAL																																
	AVERAGE SPEED HOURS																																
	1976																																
	1977																																
	1978																																
	1979																																
	TOTAL																																
	AVERAGE SPEED HOURS																																
	1976																																
	1977																																
	1978																																
	1979																																
	TOTAL																																
	AVERAGE SPEED HOURS																				[illegible]										[illegible]			
		NORTH		NNE		NE		ENE		EAST		ESE		SE		SSE		SOUTH		SSW		SW		WSW		WEST		WNW		NW		NNW	

WIND SPEED(km/h), FREQUENCY & PREVAILING DIRECTION

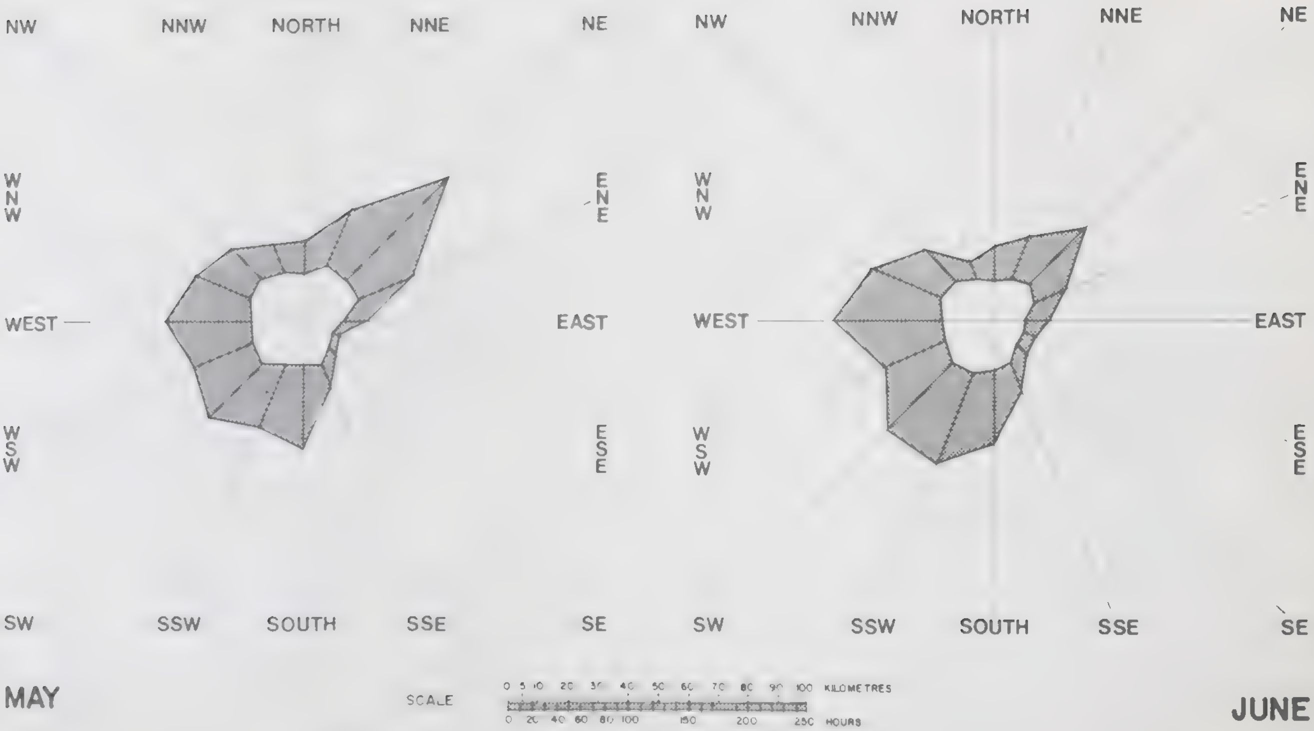
	NORTH		NNE		NE		ENE		EAST		ESE		SE		SSE		SOUTH		SSW		SW		WSW		WEST		WNW		NW		NNW	
	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS	SPEED	HOURS
1976																																
1977																																
1978																																
1979																																
TOTAL																																
AVERAGE SPEED HOURS																																
1976																																
1977																																
1978																																
1979	11																															
TOTAL																																
AVERAGE SPEED HOURS	11																															
1976																																
1977																																
1978																																
1979																												26	17	16	13	
TOTAL																												160	62	127	60	
AVERAGE SPEED HOURS																												40	16	32		
1976																												43		40		
1977																														44		
1978																														31		
1979																														26		
TOTAL																														141		
AVERAGE SPEED HOURS																														35		
1976																														25		
1977																														19		
1978																								32						22		
1979		11																						57	21	114				23		
TOTAL																								15	86					89		
AVERAGE SPEED HOURS																								54	22					22		14
1976																								197	21	75				67		
1977																								189	22	132				13		
1978	14	11																						213	26	119				14		
1979	24																							138	23	115				35		
TOTAL																								737	92	441				129		
AVERAGE SPEED HOURS	19		14																					184	23	110				32		
YEARLY AV. SPEED TOTAL HRS	14																								20	11				434	16	



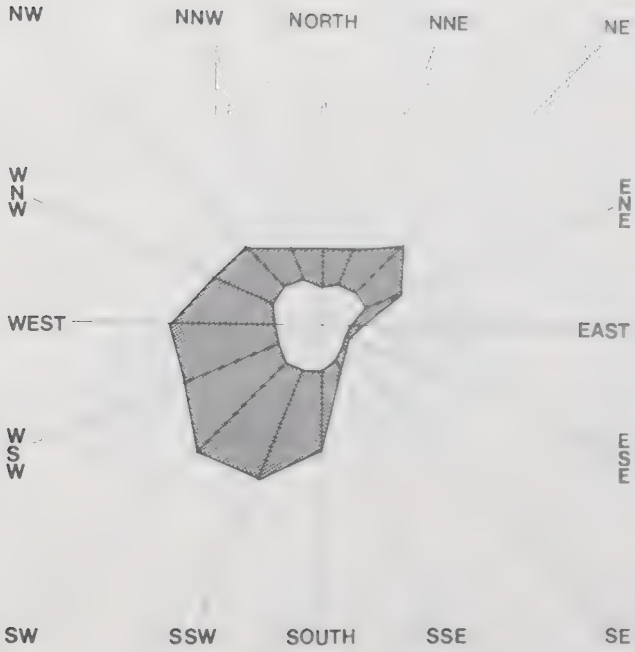
WIND SPEED(km/h), FREQUENCY & PREVAILING DIRECTION



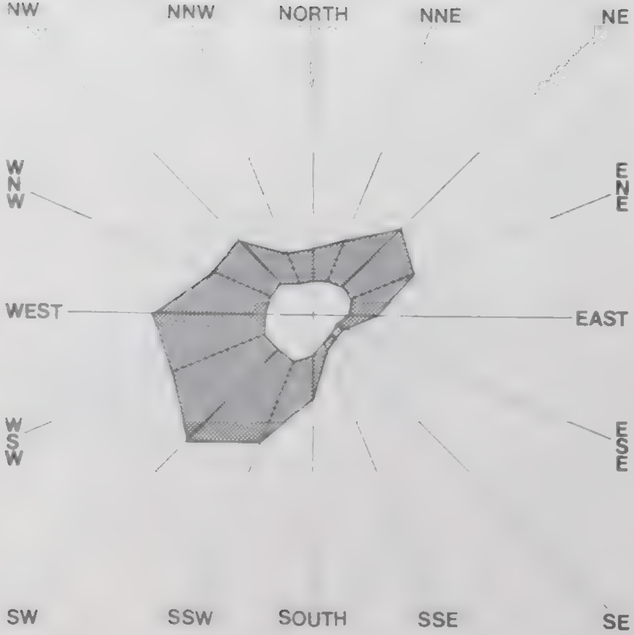
WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION



WIND SPEED(km/h), FREQUENCY & PREVAILING DIRECTION



JULY

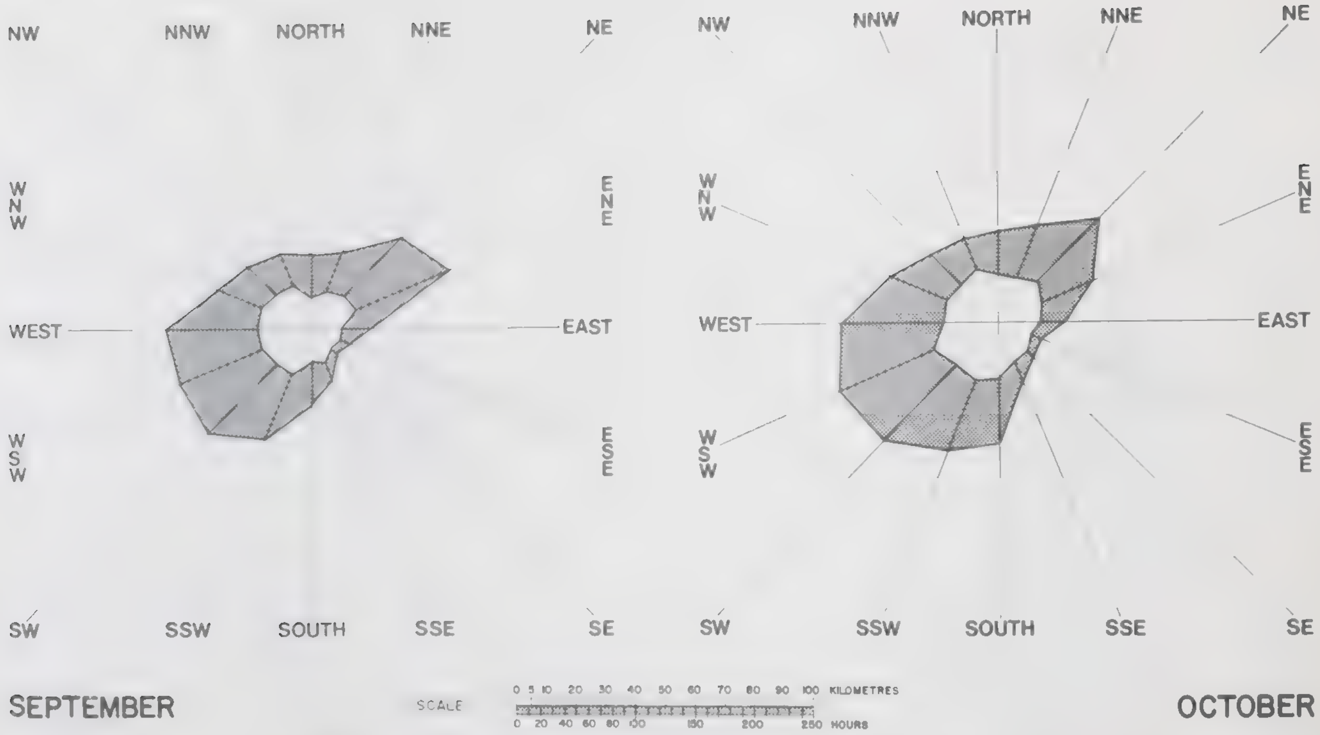


AUGUST

SCALE : 0 5 10 20 30 40 50 60 70 80 90 100 KILOMETRES
0 20 40 60 80 100 150 200 250 HOURS

WIND SPEED(km/h), FREQUENCY & PREVAILING DIRECTION

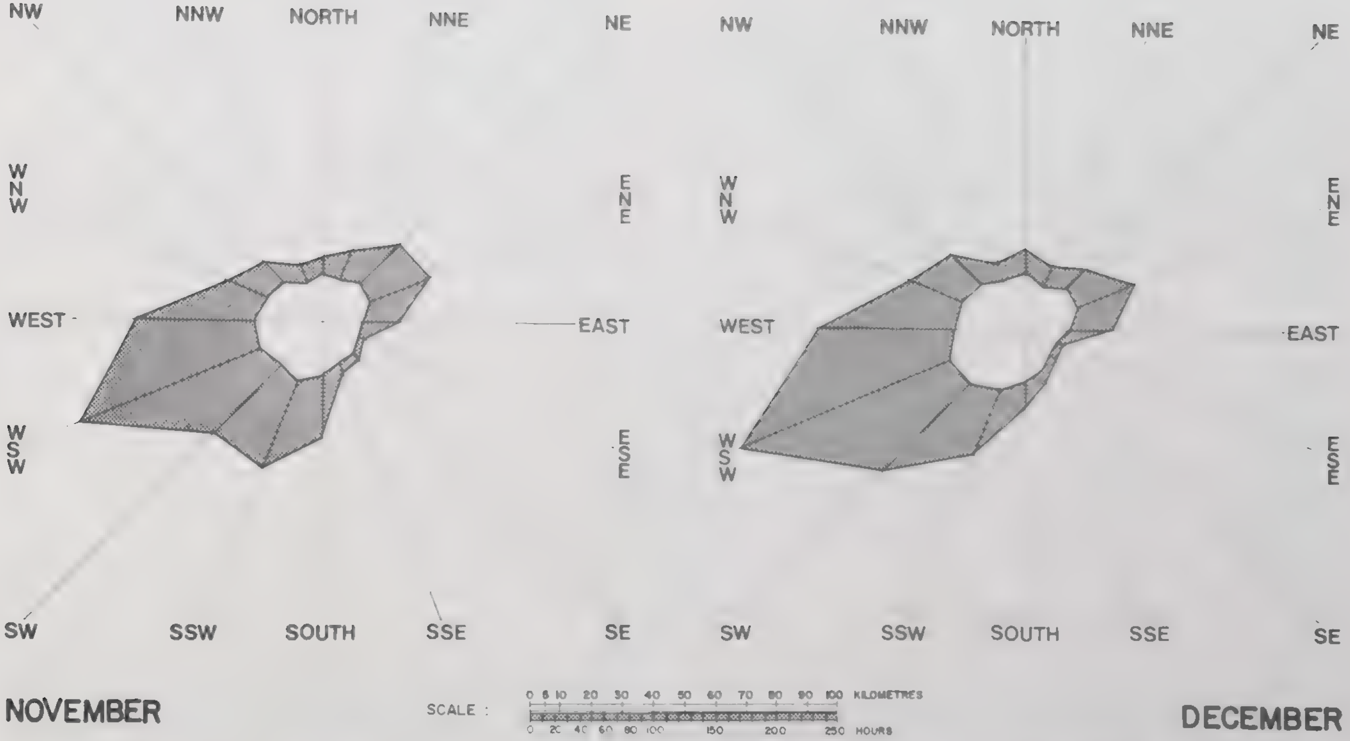
C7



SEPTEMBER

OCTOBER

WIND SPEED(km/h), FREQUENCY & PREVAILING DIRECTION



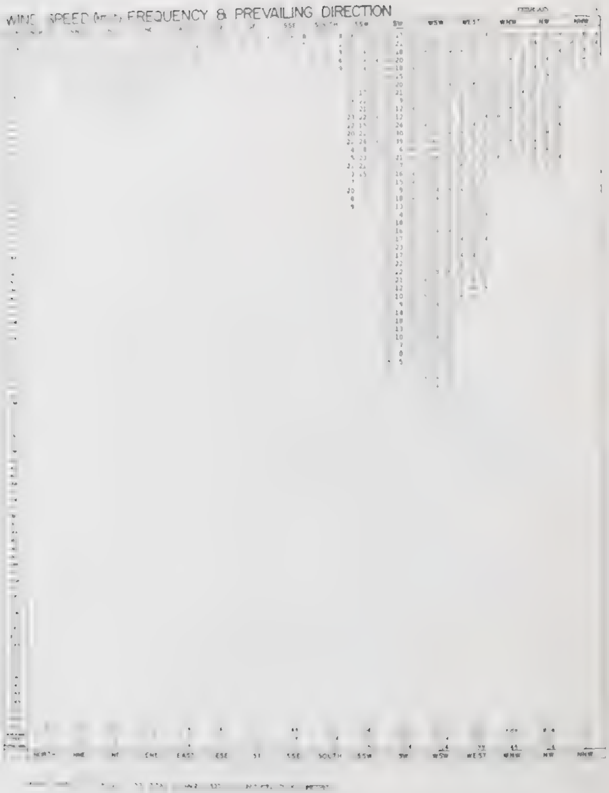
NOVEMBER

DECEMBER

WIND SPEED(km/h),FREQUENCY & PREVAILING DIRECTION

WIND SPEED FREQUENCY & PREVAILING DIRECTION

WIND SPEED FREQUENCY & PREVAILING DIRECTION



WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION

	NORTH	NNE	NE	ENE	EAST	ESE	SE	SSE	SOUTH	SSW	SW	WSW	WEST	WNW	NW	NNW
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	175	107	50	125	550	[illegible]	[illegible]	1082	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10.0	13.3	11.7	16.8	[illegible]	[illegible]	[illegible]	29.0	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15	11	8	12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] AVERAGE SPEED IS CONVERTED TO 81 [illegible]

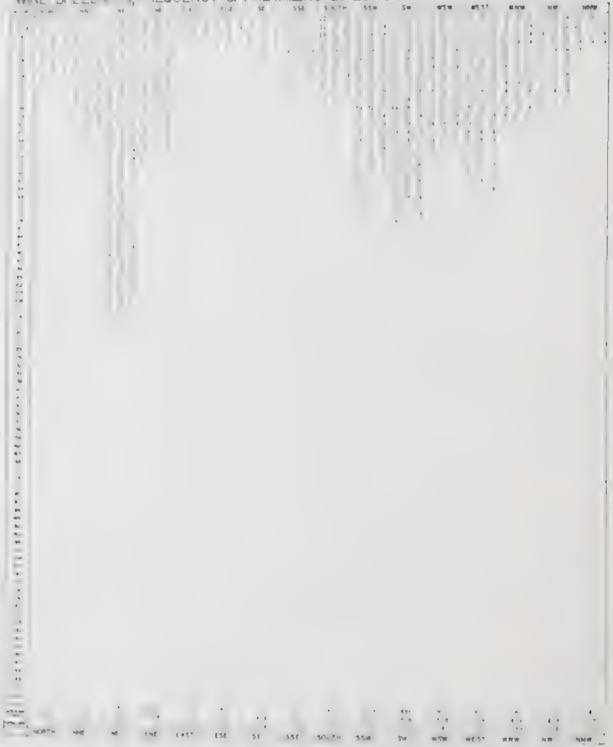
WIND SPEED [illegible] FREQUENCY & PREVAILING DIRECTION

	NORTH	NNE	NE	ENE	EAST	ESE	SE	SSE	SOUTH	SSW	SW	WSW	WEST	WNW	NW	NNW
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

WIND SPEED (MPH), FREQUENCY & PREVAILING DIRECTION

NORTH
NNE
NE
ENE
EAST
ESE
SE
SSE
SOUTH
SSW
SW
WSW
WEST
WNW
NW
NNW

WIND SPEED (MPH), FREQUENCY & PREVAILING DIRECTION


NORTH
NNE
NE
ENE
EAST
ESE
SE
SSE
SOUTH
SSW
SW
WSW
WEST
WNW
NW
NNW

WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION

WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION

WIND SPEED (MPH) FREQUENCY & PREVAILING DIRECTION

WIND SPEED (MPH) FREQUENCY & PREVAILING DIRECTION

WIND SPEED (km/h), FREQUENCY BY PREVAILING DIRECTION

WIND SPEED (km/h), FREQUENCY BY PREVAILING DIRECTION

WIND SPEED (km/h) FREQUENCY & PREVAILING DIRECTION

WIND SPEED (km/h) FREQUENCY & PREVAILING DIRECTION

WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION

	NORTH	NNE	NE	ENE	EAST	ESE	SE	SSE	SOUTH	SSW	SW	WSW	WEST	WNW	NW	NNW
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION

APRIL

	NORTH	NNE	NE	ENE	EAST	ESE	SE	SSE	SOUTH	SSW	SW	WSW	WEST	WNW	NW	NNW
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

WIND SPEED (MPH) FREQUENCY & PREVAILING DIRECTION

WIND SPEED (MPH) FREQUENCY & PREVAILING DIRECTION

NORTH	NNE	NE	ENE	EAST	ESE	SE	SSE	SOUTH	SSW	SW	WSW	WEST	WNW	NW	NNW
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	423
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	26.3

WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION

WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION

WIND SPEED (MPH) FREQUENCY & PREVAILING DIRECTION

WIND SPEED (MPH) FREQUENCY & PREVAILING DIRECTION

WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION

WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION

WIND SPEED (MPH), FREQUENCY & PREVAILING DIRECTION

WIND SPEED (MPH), FREQUENCY & PREVAILING DIRECTION

WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION

NORTH NNE NE ENE EAST ESE SE SSE SOUTH SSW SW WSW WEST WNW NW NNW

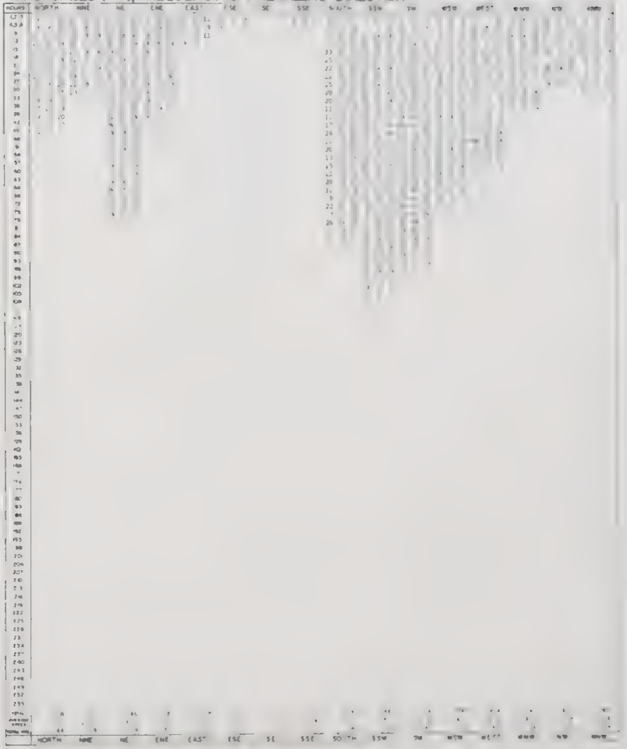
WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION

NORTH NNE NE ENE EAST ESE SE SSE SOUTH SSW SW WSW WEST WNW NW NNW

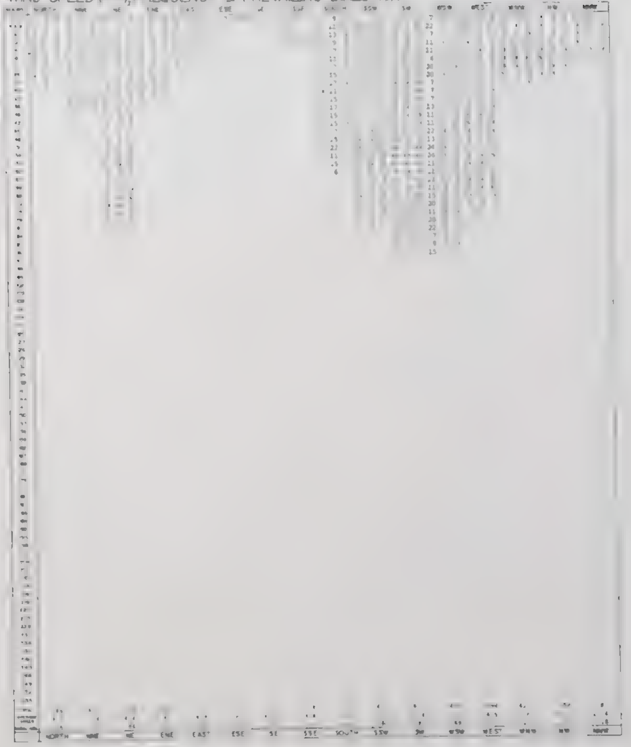
WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION

WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION

WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION



WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION



WIND SPEED (MPH), FREQUENCY & PREVAILING DIRECTION

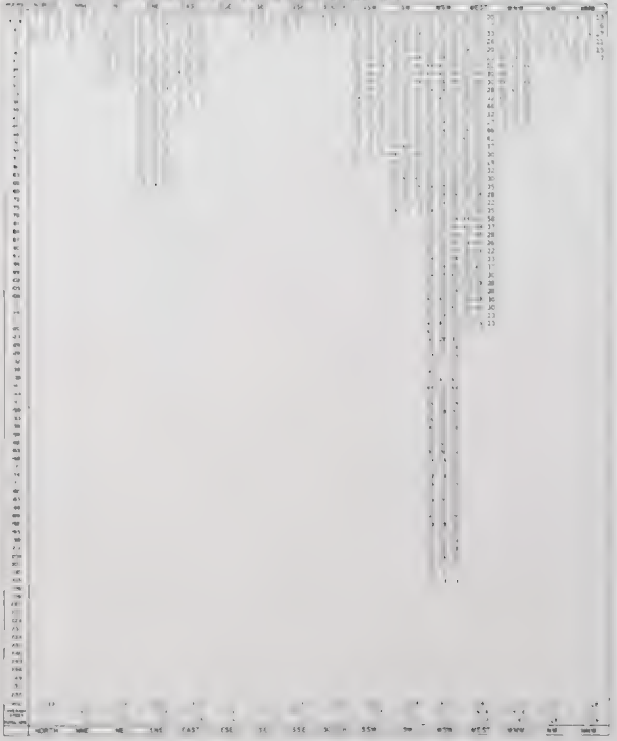
[illegible]

WIND SPEED (MPH), FREQUENCY & PREVAILING DIRECTION

[illegible]

WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION

WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION



WIND SPEED & FREQUENCY & PREVAILING DIRECTION

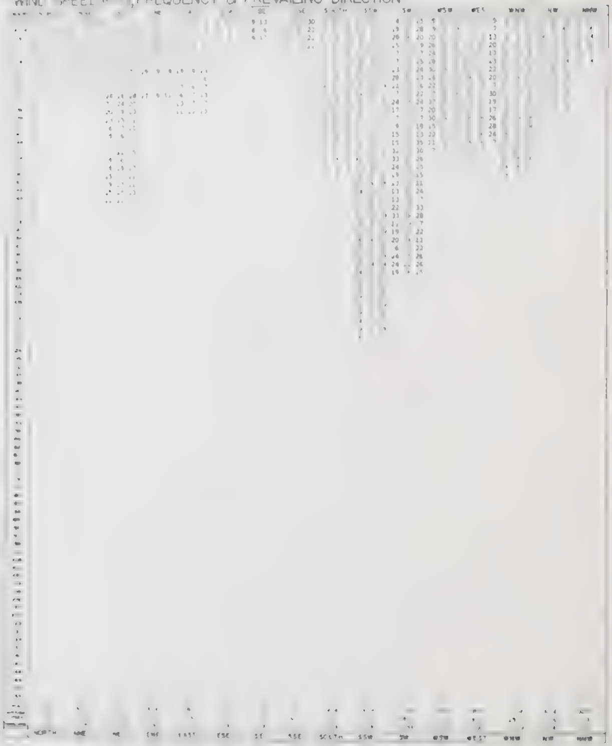
WIND SPEED & FREQUENCY & PREVAILING DIRECTION

WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION

WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION

WIND SPEED (MPH), FREQUENCY & PREVAILING DIRECTION

WIND SPEED (MPH), FREQUENCY & PREVAILING DIRECTION



WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION

NORTH NNE NE ENE EAST ESE SE SSE SOUTH SSW SW WSW WEST WNW NW NNW

WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION

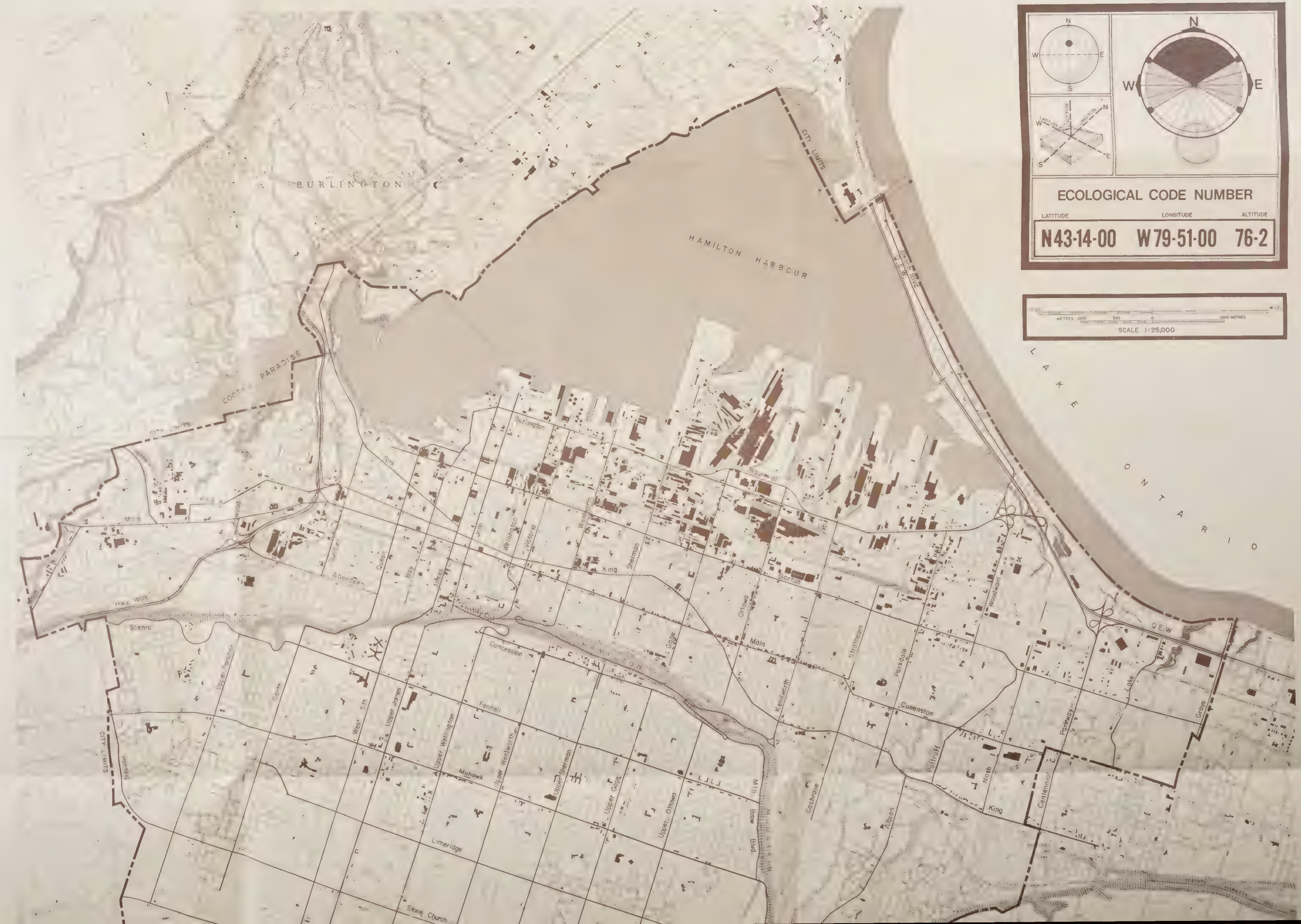
NORTH NNE NE ENE EAST ESE SE SSE SOUTH SSW SW WSW WEST WNW NW NNW

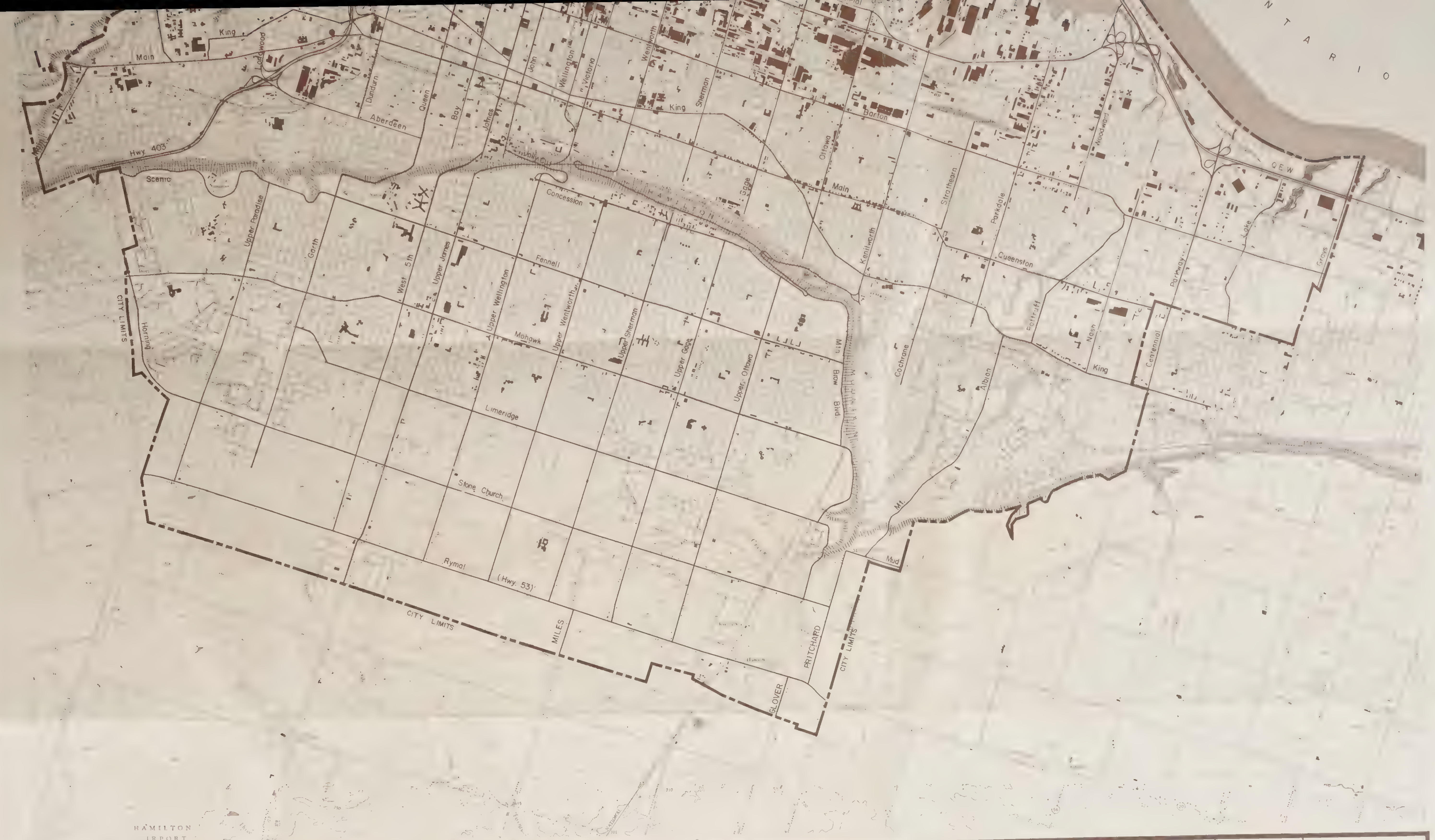
WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION

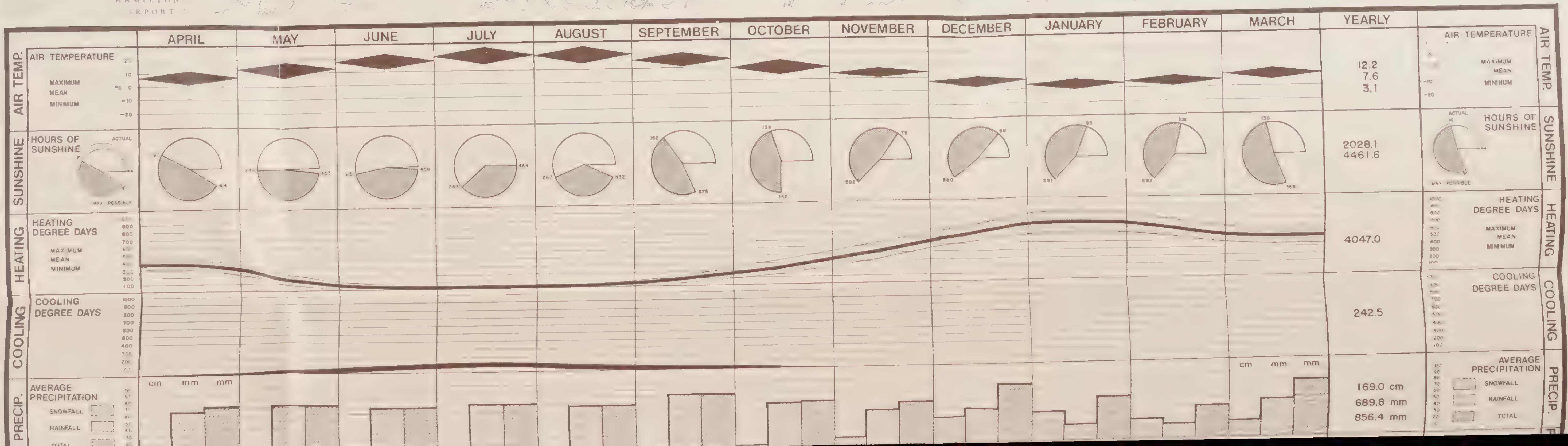
WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION

WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION

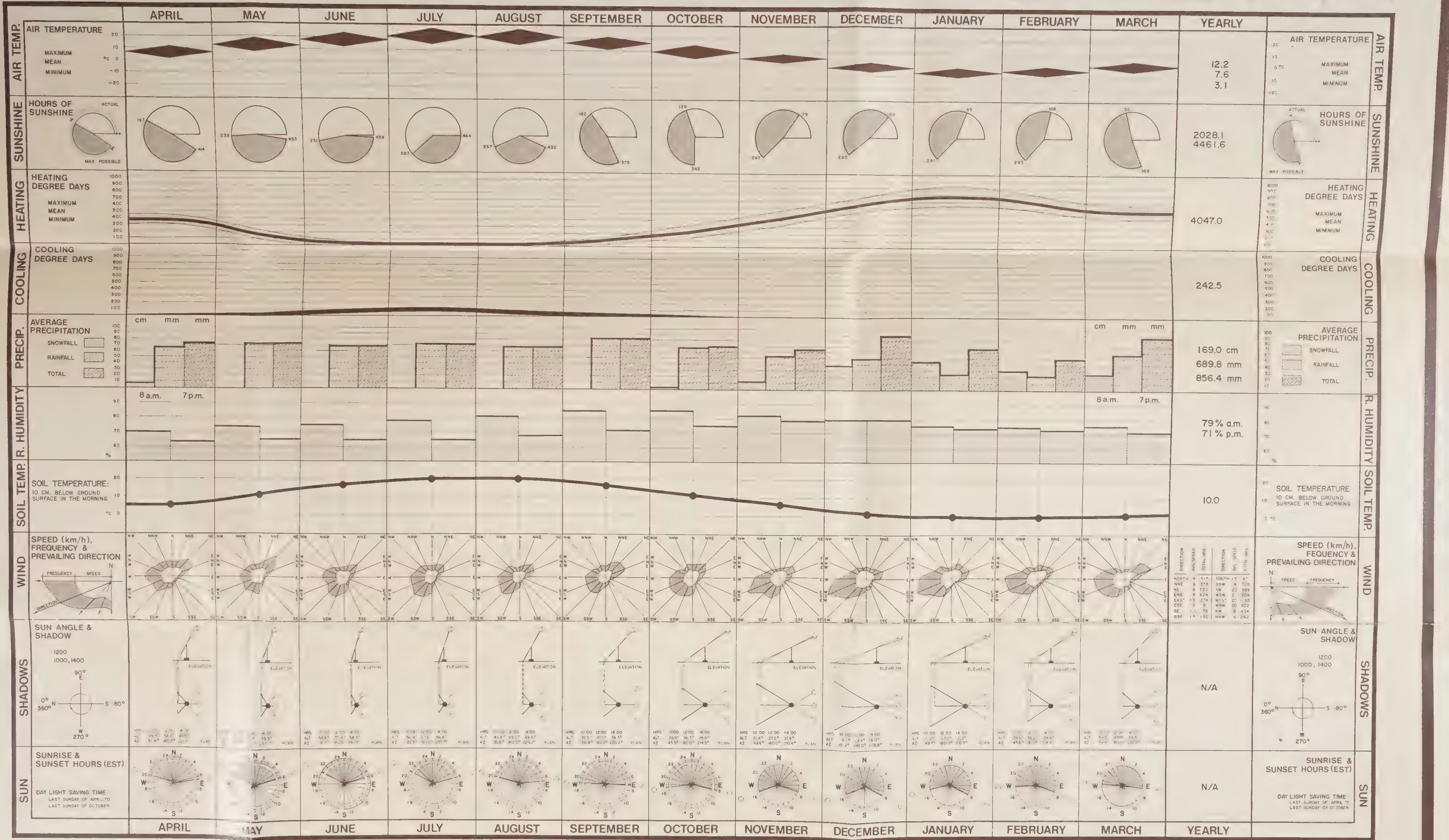
WIND SPEED (km/h), FREQUENCY & PREVAILING DIRECTION


N
W
E
S
N
W
E
S
N
W
E
ECOLOGICAL CODE NUMBER
LATITUDE
LONGITUDE
ALTITUDE
N43-14-00
W79-51-00
76-2
METRES 1000
500
0
1000 METRES
SCALE 1:25,000
BURLINGTON
HAMILTON HARBOUR
LAKE ONTARIO
CITY LIMITS
COOTES PARADISE
CITY LIMITS
CITY LIMITS
Beach Blvd
Q.E.W.
QEW
Burlington
York
Main
Main
King
King
Aberdeen
Dundurn
Queen
Bay
James
John
Wellington
Victoria
Wentworth
Sherman
Barton
Ottawa
Gage
Main
Kenilworth
Strathearn
Parkdale
Woodward
Queenston
Hwy 403
Scenic
Upper Paradise
Jolley Cut
Concession
Garth
West 5th
Upper James
Fennell
Upper Wellington
Upper Wentworth
Mohawk
Upper Sherman
Upper Gage
Upper Ottawa
Mtn Brow Blvd
Cochrane
Albion
Pottruff
Nash
King
Centennial
Parkway
Lake
Grays
Limeridge
Stone Church


N T A R I O
King
Main
Longwood
Main
Hwy 403
Scenic
Dundurn
Queen
Bay
James
John
Wellington
Victoria
Wentworth
Sherman
King
Aberdeen
Concession
HAMILTON
Gage
Ottawa
Main
Barton
Strathearn
Parkdale
Woodward
Q.E.W.
Kenilworth
Queenston
Parkway
Lake
Grays
Upper Paradise
Garth
West 5th
Upper James
Upper Wellington
Fennell
Upper Wentworth
Mohawk
Upper Sherman
Upper Gage
Upper Ottawa
Mtn. Brow Blvd.
Cochrane
Albion
Fortis
Nash
King
Centennial
CITY LIMITS
Harding
Limeridge
Stone Church
Rymal
(Hwy. 53)
CITY LIMITS
MILES
PRITCHARD
CITY LIMITS
GLOVER
Mud
Mt.
HAMILTON
IRPORT


APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
YEARLY
AIR TEMP.
AIR TEMPERATURE
MAXIMUM
MEAN
MINIMUM
°C
20
10
0
−10
−20
12.2
7.6
3.1
SUNSHINE
HOURS OF SUNSHINE
ACTUAL
MAX. POSSIBLE
414
234
453
458
287
464
267
432
162
378
139
342
79
292
69
280
95
291
108
293
136
368
2028.1
4461.6
HEATING
HEATING DEGREE DAYS
900
800
700
100
200
4047.0
COOLING
COOLING DEGREE DAYS
1000
900
800
700
600
500
400
242.5
PRECIP.
AVERAGE PRECIPITATION
SNOWFALL
RAINFALL
TOTAL
cm
mm
mm
169.0 cm
689.8 mm
856.4 mm

GLOVER
HAMILTON AIRPORT



FOR FURTHER INFORMATION SEE APPENDICES

ECOCHART OF HAMILTON

Planning and Development Department
Hamilton-Wentworth Region

JULY 1980

HAMILTON PUBLIC LIBRARY
3 2022 21334158 5